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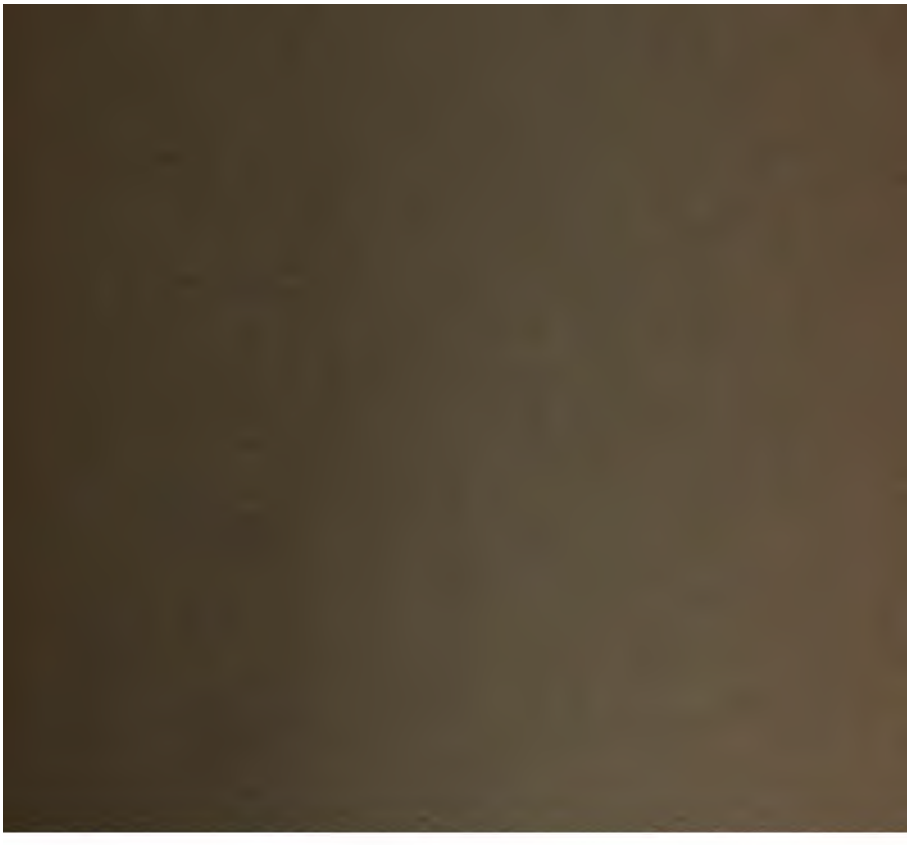
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THE

IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

ANNUAL GENERAL MEETING.

THE ANNUAL GENERAL MEETING of the IRON AND STEEL INSTITUTE was held at the house of the Institution of Civil Engineers, Great George Street, London, on Wednesday, May 24—Sir FREDERICK A. ABEL, Bart., K.C.B., F.R.S., the retiring President, in the chair.

The Minutes of the previous meeting were read, confirmed, and signed by the President.

Mr. JOSIAH J. RICHARDS and Mr. HENRY WEBB were nominated as Scrutineers by the President, and on the completion of their scrutiny they reported that the following gentlemen had been duly elected as members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Billinton, Robert John	London, Brighton and S. C. Ry., Brighton	E. Windsor Richards, Sir Jas. Kitson, A. T. Walker.
Bratt, Augustus Hicks Henery	Astor House, Shanghai, N. China	John McKillop, Herbert Pilkington, Thomas Turner.
Campbell, Thomas . .	Maryhill Ironworks, Glasgow	T. C. Hutchinson, Jeremiah Head, R. Howson.
Danks, Thomas . . .	Barrow Hæmatite Steel Co., Barrow-in-Furness	Sir Lowthian Bell, J. M. While, Charles While.
Davison, William Lynas	Codnor Park Works, Alfreton	A. L. Wright, Joseph Cook, S. Horsfield.
Echalaz, Henry . . .	4 Neville Street, Newcastle-on-Tyne	John G. Swan, W. Whitwell, A. Cooper.
Eichhoff, Otto Carl Ludwig	Sayn, Germany	Edward P. Martin, A. Thielen, A. Longsdon.
Fox, Edwin Marshall .	60 Curzon Street, Mayfair, London, W.	E. Windsor Richards, John D. Ellis, E. P. Martin.

NAME.	ADDRESS.	PROPOSERS.
Goodwin, John T. . .	Clydeview, Motherwell, N.B.	John Colville, D. Colville, jun., T. S. Paterson
Hall, Samuel Jervis .	Wainvawr, near Newport, Mon.	E. P. Martin, Isaac Butler, John Green.
Hodgson, James . .	Ulverston, Lancashire	William G. Ainslie, Myles Kennedy, F. S. Ainslie.
Hoyland, George E. .	Clarence Works, Sheffield	Joseph Newton, W. T. Flather, Robert Sykes.
Hurtzig, Arthur Cameron	2 Queen Square Place, London, S.W.	D. Macnee, R. C. Rapier, E. M. Wood.
Jones, David	Dowlais Iron Works, Dowlais	E. P. Martin, Thomas M. Percy, E. H. Saniter.
Krifka, Heinrich . .	Bruckbach-Rosenau, Upper Austria	F. Korb, C. A. Frey, Johann Oser.
Langford, William . .	Limerick Foundry, Great Bridge, Tipton	Sir A. Hickman, A. W. Hickman, Wm. Hutchinson
Laugham, William John	Wood Lane Iron Works, West Bromwich	R. Farley, James Saunders, James Roberts.
Lange, Ernest Frederick Stephen	Windsor Place, Victoria Park, Manchester	John H. Darby, Hy. B. Robertson, Sir Lowthian Bell.
Lewis, David	Gorseinon, Glamorgan	David Richards, James Jones, W. Bright.
Marsh, Arthur . . .	Roway Iron and Steel Works, West Bromwich	Richard Dalgleish, James Saunders, Henry A. Webb.
Porter, John C. . . .	Pittsburgh, Pennsylvania, U.S.A.	A. E. Hunt, George H. Clapp, W. E. Koch.
Robinson, William . .	Headingley, Leeds	W. F. Beardshaw, R. A. Hadfield, S. J. Robinson.
Salomon, Fritz . . .	Essen, Rhenish Prussia	A. Longsdon, A. Thielen, Edward P. Martin.
Silvester, Harry . . .	Handsworth, Birmingham	John H. Darby, Jas. Roberts, G. K. Harrison.
Smith, Esau Jameson .	North Ormesby, Middlesbrough	Franklin Hilton, D. Evans, I. Williams.
Smith, John Law . .	West Hartlepool	Henry Withy, Thomas Mudd, H. Le Neve Foster.
Spaeter, Carl	Coblentz on the Rhine, Germany	G. J. Snelus, A. Thielen, James Riley.
Thompson, James . .	Ettingshall Boiler Wks., Wolverhampton	Sir A. Hickman, A. W. Hickman, Wm. Hutchinson.
Wainwright, John William	Thames View, Erith, Kent	R. Colver, W. F. Beardshaw, Arthur Lee.
Wardlow, Marmaduke	Portobello Steel Works, Sheffield	T. W. Sorby, R. A. Hadfield, William Tozer.
Watts, Edgar	Cumberland Gap, Tennessee, U.S.A.	James Williams, George Wilkinson, C. D. Phillips.
Watts, Edmund Hannay, jun.	Springfield, Newport, Mon.	James Williams, George Wilkinson, C. D. Phillips.
Whitney, George Irwin	Pittsburgh, Pennsylvania, U.S.A.	Sir L. Bell, Sir James Kitson, Sir B. Samuelson.

Sir FREDERICK ABEL then read the following Report of the Council upon the proceedings of the Institute during the year 1892:—

REPORT OF THE COUNCIL FOR 1892.

During the year 1892 the Institute has made steady, and, on the whole, satisfactory progress, when the extremely depressed condition of the great industries which it specially represents are taken into account. Being a technical Society, the Iron and Steel Institute is not directly interested, as a Society, in the influence of commercial depression or of industrial distress; but the fact that these conditions existed during the year 1892 to a very marked extent, and continue to exist, has a decided effect upon the ability of members of the iron and steel industries to keep up their subscriptions, and on the readiness of others, who have hitherto kept outside, to join our ranks. Hence it is not surprising that the advance of the Institute in respect to membership has been less prominent during 1892 than in some previous years.

The number of foreign members of the Institute continues to increase, which is a satisfactory indication of the continued appreciation of its work entertained by foreign metallurgists and engineers. The soundness of the principles upon which the Institute was founded, and the utility of its deliberations and published Proceedings, are attested by the fact that similar Societies are now in successful operation in most of the iron-making countries of the world, between which and our own Institute the most cordial relations are maintained.

Equally cordial have been the relations established and maintained between the Institute and the various Local Societies that are now in existence in the principal iron-making centres of Great Britain, whose aims and objects are akin to our own. The Council fully recognise the claims and utility of subsidiary Metallurgical and Engineering Societies, such as those now established in Glasgow, South Staffordshire, South Wales, and elsewhere. The multiplication of such societies has, perhaps, a tendency to withdraw from our own certain papers that would otherwise be offered for reading and discussion at our meetings; but the Council have confidence in the position which the Institute holds as the leading Society of its kind, and believe that, notwithstanding the increasing competition for papers possessed of originality and high merit, the Iron and Steel Institute will not fail to secure its due share. The Proceedings of the Institute, up to the present time, will, it is believed, fully support this view.

The following table shows the number of members of the Instit resident in each of the principal iron-making countries of the world ot than our own at the end of 1892 :—

FOREIGN MEMBERS OF THE IRON AND STEEL INSTITUTE, DECEMBER 31ST, 1892.

In the	United States	102
,,	France	39
,,	Germany	47
,,	Belgium	14
,,	Spain	15
,,	Austria	10
,,	Russia	6
,,	Sweden	6
,,	India	3
,,	Canada	3
,,	New South Wales	3
	Total	248

In addition to the above there are members in China, Singapore, the United States of Colombia.

DECEASES AND RESIGNATIONS DURING 1892.

An unusually high death-rate appears to have occurred among members of the Institute during the year 1892. The following is a list

Names of Members Deceased during 1892.

J. A. Andrew.
James Allan.
Sir James Brunlees.
Saml. H. Byrne.
Benj. Carruthers.
T. W. Crawhall-Wilson.
Edwd. F. Crippin.
Wm. L. Darling.
William Firth.
P. W. Flower.
Michael H. Grazebrook.
Robt. Horsburgh.
Richard S. Johnston.
Hermann L. Lange.
Wm. Mackinnon.
Henry Jno. Marten.
P. M. Parsons.
Maskell W. Peace.
G. J. W. Ridehalgh.
Edward Ross.
George Ryder.
C. J. Schofield.
Wm. P. Shinn.
David Simons.
Matthew H. Simpson.
E. Fisher Smith.
Duke of Sutherland, K.G.
James Taylor.
John Varley.
Walter Williams.
Henry Woolcock.
John Worton.

In addition to the foregoing removals by death, an unusually large number of members of the Institute have resigned during the year; but this is no doubt largely, if not mainly, attributable to the serious depression that has been already referred to, and the consequent stoppage of many works and furnaces.

General Meetings in 1892.

Two General Meetings of the Institute were held during 1892, as usual. The Spring Meeting was held on the 26th and 27th days of May, at the Institution of Civil Engineers, whose constant courtesy in providing facilities for such occasions the Council would again gratefully acknowledge. The Autumn Meeting was held in St. George's Hall, Liverpool, on the 20th and three following days of September. The Council consider that the papers read on those occasions maintain the high character of the Society's Proceedings for interest and value. Their titles are as follows :—

Papers read at the Spring Meeting.

On Experiments with Basic Steel. By W. H. White, C.B., F.R.S., Director of Naval Construction and Assistant-Controller of the Navy.

On the Production of Pure Iron in the Basic Furnace. By Colonel H. S. Dyer, Elswick Works, Newcastle-on-Tyne.

On Experiments on the Elimination of Sulphur from Iron. By E. J. Ball, Ph.D., and A. Wingham, F.I.C., London.

On Platinum Pyrometers. By H. L. Callendar, London.

On the Manufacture and Application of Chilled Cast Iron (Gruson's System). By E. Reimers, Technical Director of the Gruson Works, Magdeburg.

On Valves for Open-Hearth Furnaces. By J. W. Wailes, Calderbank, near Glasgow.

On a Practical Slide-Rule for Use in the Calculation of Blast Furnace Charges. By A. Wingham, F.I.C., London.

Notes on Fuel, and its Efficiency in Metallurgic Operations. By B. H. Thwaite, Liverpool.

The following paper was taken as read, and published in the first volume of Proceedings for 1892.

On the Calorific Efficiency of the Puddling Furnace. By Major Cubillo, Trubia Arsenal, Spain.

Papers Read at the Autumn Meeting.

On the Manufacture of Iron in its Relations with Agriculture. By Sir LOWTHIAN BELL, Bart., F.R.S.

On an Apparatus for Autographically Recording the Temperature of Furnaces. By Professor W. C. ROBERTS-AUSTEN, C.B., F.R.S.

On Alloys of Iron and Chromium. By R. A. HADFIELD, Sheffield.

On the Liverpool Overhead Railway. By J. H. GREATHEAD, M.I.C.E., London.

On Failures in the Necks of Chilled Rolls. By CHARLES A. WINDER, M.I.M.E., Sheffield.

On a New Process for the Elimination of Sulphur. By E. SANITER, Wigan.

On the Elimination of Sulphur from Iron. By J. E. STEAD, Middlesbrough.

On the Engineering Laboratories in Liverpool. By Professor H. S. HELE-SHAW, Liverpool.

A new departure was made at the Autumn Meeting of 1892, in so far as receptions and entertainments are concerned. Hitherto it has been the custom for the members of the Institute, and others friendly to it, resident in the places or districts visited, to provide funds for the purpose of affording hospitality to the Institute. These funds have in some cases assumed large proportions, and the Council have for some time past felt that a tax has been thus imposed upon the resources of the localities visited, that was likely to become more serious as the Institute assumed larger proportions, and might, in course of time, interfere with the readiness of desirable districts for meetings to extend invitations for our Autumn gatherings. This view was strengthened by the fact that several other Societies, having much in common with our own, are competitors for the favour of such invitations. The Council therefore decided, last year, to discourage, in so far as in them lay, the raising of local reception funds, and a commencement was made with the new system at the Liverpool Meeting of 1892. They believe that the result demonstrated the wisdom of the course adopted, the Liverpool Meeting having been in all respects successful; no special reception fund was raised for entertainment purposes, but the Institute was treated with much hospitality and courtesy in many directions.

The Council have specially appreciated and recognised the courtesy of the Mayor of Liverpool, in giving an invitation to the Institute to visit Liverpool, in forming a Reception Committee and in otherwise assisting to make the meetings a success. They also desire to refer in grateful terms

to the kindness and hospitality of the Mayor of Chester; of the Duke of Westminster; of Messrs. R. Heath & Sons, of Stoke-upon-Trent; of Mr. J. W. Willans, the contractor for the Liverpool Overhead Railway; of the Lancashire and Yorkshire and London and North-Western Railway Companies, who provided special trains for excursions; and of the owners of important works, who freely permitted members to see over their establishments, and afforded explanations of matters of interest.

The Chicago Exhibition of 1893.

The Council have from time to time had the most cordial assurances from the various Engineering Societies of the United States, and from the officials of the World's Fair at Chicago, that a very warm welcome would be extended to any members of the Institute who might visit the Exhibition, whether as a body or individually. The Institute has also been invited to take a part in the various engineering and allied conferences which it is proposed to hold in Chicago during the continuance of the Exhibition.

The Institute having, as a body, visited the United States so recently as 1890, the Council have not deemed it advisable to make any effort to organise another special visit of members to that country in the course of the present year. They have been guided to this conclusion by finding, as a result of having invited members to state their intentions in the matter, that not more than sixty had decided to go to Chicago, and that the months most convenient to individual members for such intended visits varied greatly, commencing with April and ending with October. Under the circumstances, the Council did not see its way to do more than to issue to the members such information relative to the Chicago Exhibition as was most likely to be interesting and useful, including the various proposals and invitations submitted by the several Engineering Societies. Those members who may decide to visit Chicago are likely to find very complete arrangements made by these organisations for their convenience and comfort.

One of the most interesting features of the World's Fair from the point of view of the Iron and Steel Institute is likely to be the Engineering Congress, which it is proposed to hold in August, and for which papers are invited from members of this Institute. Mining and metallurgy will be dealt with by the American Institute of Mining Engineers, which took so prominent a part in the reception of the Iron and Steel Institute in 1890, and any of our members who may wish to make communications bearing on these subjects may communicate either with Dr. Raymond.

the Secretary of that body (at 13 Burling Slip, New York), or with Mr. E. L. Corthell, the Chairman of the Executive Committee (at the Temple, Chicago).

Retiring Members of Council.

The retiring members of Council are :—

Vice-Presidents.

William Jenkins. Edward P. Martin.
Sir James Ramsden.

Members of Council.

Wm. Beardmore. Benjamin Hingley, M.P.
Andrew Carnegie. Arthur Keen.
R. A. Hadfield.

All of whom are eligible, and offer themselves for re-election. No other names having been submitted, the retiring Members of Council will be continued in office.

The Bessemer Medal for 1893.

The Bessemer medal for 1893 has been awarded to Mr. John Fritz, of the Bethlehem Steel Works, Bethlehem, Pennsylvania, who is well known on both sides of the Atlantic as a metallurgist and engineer of high attainments.

Resignation of the Secretary.

The members of the Institute will regret to learn that Mr. J. S. Jeans, who has held the post of Secretary for sixteen years, has recently resigned that office. The Council, in accepting his resignation, have recorded their high appreciation of the services which Mr. Jeans has rendered to the Institute, and have given substantial form to their recognition of his faithful devotion to its interests. Opportunity has been taken by the Council of Mr. Jeans' retirement to introduce some modifications in the organisation of the secretarial and editorial arrangements, and Mr. Bennett H. Brough, A.R.S.M., who has for some time past been an assistant-professor at the Royal College of Science, and one of the abstractors of foreign papers for the Journal of the Institute, has been appointed to the conjugate office of Secretary and Editor.

The Honorary Treasurer (Mr. David Dale) read the Annual Statement of Accounts (p. 9).

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNTS FOR THE YEAR ENDING DECEMBER 31, 1892.

RECEIPTS.				EXPENDITURE.			
To Entrance Fees	£115 10 0			By Balance due to Treasurer, December 31, 1891			£403 3 2
,, Subscriptions	3040 16 0			,, Salaries of Secretary and Clerks	£742 0 0		
,, Journals and American Volumes sold	152 18 0			,, Office Rent, Cleaning, &c.	334 2 6		
,, Interest	302 7 5			,, Purchases for Library and Office Furniture	12 6 6		
,, Bessemer Modal Fund Interest	15 12 0			,, Editing and Translating	225 13 2		
		£3627 3 5		,, Expenses in connection with Annual Meeting in London, May 1892	28 11 0		
,, Balance due to Treasurer		1278 5 3		,, Expenses in connection with Meeting at Liverpool, August 1892	183 10 9		
				,, Journal Publishing Expenses	933 15 7		
				,, Printing, Advertising, and Stationery	332 11 0		
				,, Insurance	2 2 6		
				,, Bessemer Medal	15 10 0		
				,, Inland Revenue-Corporation Duty	18 18 7		
				,, Postages, Receipts, &c., per Treasurer and Secretary	116 7 4		
				,, Sundry Payments	57 8 4		
					£2997 17 8		
				,, Special American Journal (referred to in last year's Statement	944 10 0		
						3942 7 8	
				,, Addition to Invested Funds— £330 North-Eastern Darlington 5½ per cent. Stock, at a cost of		559 18 8	
		£4905 8 8					£4905 8 8

May 18, 1893.

(Signed) DAVID DALE, *Hon. Treasurer.*

INVESTED FUNDS OF THE INSTITUTE.

£1500 North-Eastern Darlington 5½ per cent. Stock, purchased at a cost of	£2298 7 0
£1681 North-Eastern 1876 4 per cent. Preference Stock, purchased at a cost of	1998 19 7
£830 North-Eastern Darlington 5 per cent. Stock, purchased at a cost of	1008 14 0
£1546* Scinde, Punjaub, and Delhi 5 per cent. Stock, purchased at a cost of	1999 0 7
£750 Great Indian Peninsula Railway 5 per cent. Stock, purchased at a cost of	1267 6 0
	£8572 7 2

* This has since been compulsorily converted into an Annuity up till 1958, with a Sinking Fund to replace the amount of Stock, £1546.

Sir FREDERICK ABEL, having read the report of the Council, moved its adoption.

Mr. T. BARLOW-MASSICKS said he had great pleasure in seconding the adoption of the very able Report just read. It must be a great satisfaction to the members of the Institute to find it increasing year by year as they grew older. He was himself an original member of the Institute, and it was a great satisfaction to him to notice at its head some of the familiar faces that they had known for so many years. Long might they be spared, and long might the Institute flourish.

The motion was unanimously adopted.

Mr. JEREMIAH HEAD moved, "That the most cordial thanks of the members of the Iron and Steel Institute be and are hereby tendered to the President, the Council, and the Honorary Treasurer for their services during the past year." With regard to the President, since the Institute had been founded many years ago, they had had a very large number of able and eminent Presidents, but among them there was none more eminent, and none, he believed, who had fulfilled his duties more faithfully and more to the entire satisfaction of the members than Sir Frederick Abel. Her Majesty the Queen had lately been pleased to confer additional honour on him, and he was sure that the members would agree with him in thinking that they might take a little of the reflected honour upon themselves. Sir Frederick Abel deserved the honour that had been conferred upon him, and they did not forget than when it was conferred he was President of the Institute.

With reference to the members of the Council, the ordinary members, who came to the meetings from time to time and profited by the proceedings, could only know to a very slight extent the labour and the assiduity of the members of the Council, who met much more frequently than the ordinary members did, and made all the arrangements which were so conducive to their enjoyment and instruction. Once a year only the members had the opportunity of letting them know that they were not forgetful of those labours nor ungrateful for them. He

therefore asked the meeting heartily to respond to the resolution which he proposed.

With regard to the Honorary Treasurer, he was one of the most important officers of the Institute. Unless their accounts were kept in good order, it was impossible for them to thrive as they were doing, and he was quite sure that so long as Mr. Dale had charge of their finances they would be in a sound and satisfactory condition. He therefore asked the members to include Mr. Dale's name in the vote of thanks which he had the honour of proposing.

Mr. R. PRICE-WILLIAMS, in seconding the resolution, said that Mr. Head had left him very little to say, but he had afforded him the opportunity of expressing the great regret which he was sure was felt by the members generally at the resignation of their worthy Secretary, Mr. Jeans. Looking back upon his career in connection with the Iron and Steel Institute, every one must recognise the great value of his services, and the indefatigable way in which he had attended to his duties.

The motion was unanimously adopted.

Sir FREDERICK ABEL said that, on behalf of his colleagues and himself, he desired to return their cordial thanks for the appreciation just evinced of their endeavours to promote the interests of the Institute, and to uphold the importance of its work in every possible direction. He was glad that he could congratulate the members upon the years that had passed since he had the honour of being appointed President. They had not been brilliant years, but they had been of great interest in the history of the Society, and they could certainly congratulate themselves on having received communications as important as any that had appeared in the annals of the Institute.

His last act, and one of the most pleasant acts which the retiring President had to perform, was that of introducing to the members—a work of supererogation on his part—the President for the present year, Mr. Windsor Richards. It was not necessary again for him to go over the long list of Mr Richards' qualifications, which rendered him, in the opinion of his colleagues, most eminently fitted to occupy the chair of that im-

portant Institute. They were all looking forward with great interest and satisfaction to his wise rule. He had been amongst them a constant adviser and a friend to all, and they were perfectly sure that in his hands not only would the Institute not suffer, but it would gain very much. He would now ask the President to be so good as to take the chair and deliver his address.

Mr. E. WINDSOR RICHARDS then delivered the following Presidential address :—

PRESIDENTIAL ADDRESS.

In taking this chair, which has been so ably filled by many eminent men, well qualified by their learning, eloquence, and business abilities to advance the best interests of the Institute, you will, I am sure, understand my feelings of diffidence and fear that, under my Presidency, the Institute may not be as prosperous and useful as it has been in the past.

I give you my most earnest assurance that, however great my shortcomings may be, I will do all that lies in my power to further your interests to the best of my ability, and I thank you very sincerely for the great honour you have conferred upon me by electing me to the proud position of President of the Institute.

I feel sure of the cordial co-operation of my colleagues of the Council, and I beg the hearty support of the whole of my fellow-members and request their attendance at the meetings. I particularly desire that the younger members should volunteer papers and join more in the discussions than they have hitherto done.

The Institute continues to prosper and makes substantial progress. The Treasurer's statement for last year shows a satisfactory balance in hand.

The two General Meetings held in 1892 were not inferior in point of interest and attendance to their predecessors, and that, too, in face of the fact that the Council for the first time determined to dispense with the Local Entertainment Fund, which had in some cases become a serious tax upon the Committee prepared to receive us.

It cannot be doubted that the meeting held in Liverpool in September last was eminently successful in all respects, without an entertainment fund, and this fact encourages the Council to hope that certain localities, that have not yet received us, may have no hesitation in doing so in the future. The Council have received several communications from engineering societies in America extending a cordial invitation to our members to assist at the several congresses on engineering and cognate subjects,

arranged as auxiliaries to the World's Fair. The Council do not propose to make any special provision for the transportation of members to that Exhibition, but have appointed three of their members, Mr. Hadfield, Mr. Snelus, and myself, to be delegates from the Institute to those congresses. Any of our members visiting the Exhibition and taking part in the congresses organised in connection therewith, may rely on a most hearty welcome.

In the Report of the Council reference is made to the resignation of the Secretary and to the appointment of his successor. Mr. Jeans has been Secretary of the Institute for sixteen years —two-thirds of the whole life of the Society. The remarkable progress made during his term of office must be a source of much satisfaction to him on retiring from the position he has so well and so long filled. Mr. Bennett Brough, who succeeds Mr. Jeans, has been known to many of us as an efficient abstractor for the *Journal*. We hope that during his term of office the career of the Institute may be equally prosperous.

It is difficult to decide upon what shall be the drift and scope of a Presidential address.

Sir Lowthian Bell pointed out the desirability of alternate scientific and practical Presidents. I consider myself in the latter category, and, guided by his expression of opinion, I have thought that I would confine my remarks to practical points, and that I might with advantage in this address, as far as time will permit, review some of the developments which have been attained in the metallurgical operations of our iron and steel works. Thus, by recording the various stages of perfection arrived at in those industries in the spring of 1893, a standard of reference, whereby future advances and improvements may be measured, will be in some degree available.

The present meeting is held under circumstances of great depression and gloom for the iron and steel trades. The year 1892 was, in many respects, one of the very worst those industries have ever known. The production of pig iron fell off to the extent of over 600,000 tons. The production of wrought iron and steel was also much under that of some previous years. The most serious falling off, however, was in the production of steel rails. The export of rails in 1892 was not much more than one half of that of

1890, while the exports of 1890 were much under those of some previous years. The total falling away in our exports of metals and machinery in 1892 as compared with 1891 amounted to over seven millions sterling.

One characteristic of the iron industry of the past year has been the great diminution in the quantity of pig iron made from English ores.

The imports of iron ore from Spain during 1892 amounted to $3\frac{3}{4}$ millions of tons, equal to a production of 1,800,000 tons of pig iron.

The total quantity of pig iron made in this country in that year was 6,616,890 tons, so that 26 per cent. of the whole production was made from imported ores.

It is remarkable how all the principal iron-making districts have of late years increased their consumption of imported ores and reduced the use of home ores.

In Scotland, the make of well-known brands of Scotch foundry iron has been largely reduced from year to year, until now more than 24 per cent. of the production is obtained from foreign ores.

South Wales has practically ceased raising ironstone, and depends almost entirely on foreign supplies. Cleveland has immense quantities of phosphoric ironstone at its door, cheaply won, but 20 per cent. of its total make of pig iron comes from ores carried more than a thousand miles.

Even Lancashire and Cumberland, with hæmatite ores of the highest quality close at hand, have of late years extended their use of Spanish ores.

Is it possible for the north of Spain, which in 1892 supplied us with $3\frac{1}{4}$ millions of tons of ore, to maintain that output for a much farther length of time?

It is generally thought that the most valuable and extensive deposits are being rapidly exhausted, and that some of the most productive mines are not likely to last more than a few years longer.

Last month I visited Bilbao, and made careful inquiries from competent authorities on the spot, and learned that, with the exception of the large mines owned by the Orconera and Franco-Belge Companies, there are no very extensive deposits left to be worked.

Indeed, were it not for the recent successful calcination of the spathic ores which underlie the Rubio ore, the duration of the district, at the present rate of output of four millions of tons per annum, would have been within measurable distance; but there are very large deposits of spathic ore, the depth and extent of which are as yet unproved. Calcining operations will in the near future be largely carried on, making the spathic ore, which in the raw state contains 43 per cent. of iron and 25 per cent. of carbonic acid, give in the calcined condition 58 per cent. of iron, thus making a very valuable mineral, having only 2 per cent. of moisture as received. Calcining kilns are already erected, one large kiln economically and effectually calcining 1500 tons of raw ore weekly. It seems probable that this successful dealing with the spathic deposit will extend the life of the district fully ten years. It must be understood, however, that this length of life does not apply to the Orconera and Franco-Belge properties.

There are large deposits of ores free from phosphorus in the neighbourhood of Seville and in the south of Spain that will become available, but considerable sums of English money will have to be expended in opening out the mines and conveying the mineral to the ship; but, in the words of Mr. Gill of the Orconera Company, who has seen all the recently discovered large deposits, "there is as yet only one Bilbao."

Under these circumstances, it is natural that our attention should be arrested by the inquiry, whether, if the Spanish supplies were to be suddenly cut off, we could depend wholly on our home mines? The West Coast has raised 2¾ millions of tons of ore free from phosphorus, and could most probably increase that quantity to produce 1½ millions of tons of pig iron, should the demand arise.

During the twelve months ending December 1892, the quantity of basic steel made in England was 406,839 tons, of which 108,056 tons was open-hearth steel.

In Germany and Luxemburg, 2,013,484 tons of steel was made from phosphoric ores, of which quantity 186,252 tons was open-hearth, the balance being basic Bessemer steel.

Very much more prejudice has existed in England than on the part of Continental buyers against the use of steel made by

the basic process. This seems only natural, when no difficulty existed here in procuring ores free from phosphorus, and in the event of foreign supplies being cut off, such prejudice would doubtless quickly disappear.

There need, therefore, be no apprehension of our being unable to supply all the iron and steel we may be called upon to produce. Indeed, the great trouble seems to be that of being able to procure sufficient work to keep our large establishments employed. We could quickly make ourselves independent of foreign supplies of ores, except in the manufacture of spiegeleisen and ferro-manganese, with high percentages of manganese, and in this respect we are entirely dependent on foreign countries, the English spathic ores not being rich enough to give above 10 per cent. of manganese in spiegeleisen.

I.—Blast-Furnace Practice.

The visit of the Institute to America is so recent, and the papers read there, with the discussions, are so fresh in your memories, that it is not desirable to repeat here any records of the large productions attained from a blast-furnace, especially as all the information then gathered has been fully recorded in the *Journal* of the Institute; but I cannot allow this reference to the visit of the Institute to the United States to pass by without again sincerely thanking our American friends on behalf of the members, as well as on my own behalf, for their most cordial and splendid reception; their kindness and hospitality were unbounded, and will always be remembered with pleasure by those who were fortunate enough to visit that great country.

In England we have been obliged to be content with such outputs per furnace as the usual complement of men can fairly deal with; indeed, there has been no inducement to increase production, for the blast-furnace power of the country is far in advance of the demand for pig iron, so that our attention has been more directed to economical working than to large yields.

Bolckow, Vaughan, & Co., at Eston, in a plant erected in 1877, with a 50 per cent. ore make a thousand tons of hot-blast pig iron per week, with 19 cwt. of coke, in a furnace of the following dimensions:—Height, 72 feet; bosh, 23 feet in diameter, having an

angle of 72°; throat, 15 feet in diameter; bell, 11 f
feet; Cowper stoves of sufficient capacity to give
daylight; number of tuyeres, 6; diameter of muzz
of blast, 5¼ lbs.

The total cost of labour per ton of pig iron i
this includes everything connected with the b
materials for the making and the removal of the p
we consider that the whole of the ore, coke, and lim
ing to about 3500 tons per week, is handled by tw
the blast-furnace, we must admit that it does not
that this labour-cost can be appreciably reduced.
tion of the iron made is conveyed in a molten co
after passing through a "mixer," is taken direct t
converter.

At the Dowlais Company's new works at Cardi
P. Martin has attained a production of upwards o
week, using the usual Rubio ore, and with rathe
cwts. of coke per ton of pig iron, 70 per cent. of th
No. 1 quality. The furnace is 75 feet high; bosh,
an angle of 78°; throat, 15 feet 6 inches; bell, 11
10 feet; Cowper stoves, giving an average tempe
Fahr.; number of tuyeres, 7; diameter of muz
pressure of blast, 5½ lbs.

One pair of compound condensing blast-engines
each furnace having high-pressure steam cylinde
diameter, and low-pressure cylinders 64 inches dia
cylinders 88 inches diameter, all of them 5 feet str
revolutions per minute 23, giving 19,000 cubic
atmospheric pressure per minute. Each pair of
rately connected to the blast-furnace.

There has been no attempt made to drive the
production requiring any increase in the number
employed, so that the results are very satisfactory,
cost as low as that before mentioned. With such
tion of pig iron, all of which is allowed to becon
beds, some difficulty in clearing away the metal w
so an apparatus was devised for dealing with th
breaking up of the pig iron by mechanical mea

PLATE I.

BREAKER



Ballantyne, Hanson & Co., Edinburgh & London.

PLATE II.

BREAKER.



Ballantyne, Hanson & Co., Edinburgh & London.

beds quickly, to reduce the cost of labour, and above all, to dispense with a difficult and exacting class of workmen, which at any moment has the power, and sometimes exercises it, of bringing the works to a stop.

This apparatus (Plates I. and II.) consists of quick-running overhead steam-travelling cranes, which sweep the whole surface of the pig-beds. The breaker is fixed at the far end of the line of furnaces, and when the whole of the four blast-furnaces are completed, a second breaker will be placed at the other end.

It is important that the pigs should be moulded at quite equal distances apart, and means are devised for ensuring this, so that the three fixed hammers on the hydraulic rams may exactly suit the distances of three pigs. The beds, being thus moulded, are cast in groups of thirty pigs. The group is not meddled with in any way till it has become cool. The overhead crane then picks up the whole group of thirty pigs, and runs with it, at a high speed, to the breaker, depositing it on a light four-wheeled carriage running on an incline towards the breaker, thus enabling the workmen to push forward easily the loaded carriage. On arrival, the group is drawn forward by a pawl of sufficient length of stroke to place the group of pigs under the hydraulic ram, which, at one stroke, breaks three pigs, though only one at a time, the sow being broken by a second ram. The four pieces of broken pig slide down a strong shoot into a railway waggon, the detached sand falling between the bars forming the shoot.

One machine can readily deal in this way with 4000 tons of pig iron weekly, working only from eight to ten hours daily.

The operations are all conducted by young men of ordinary physique, and the whole cost of carrying away the iron, breaking the pigs, &c., is covered by a charge of 1½d. per ton.

Among other advantages is the easy stocking of the pig iron, owing to the group system of casting the fresh fractures from the breaker, showing the quality of the iron, no matter how much it may have become rusted, while the rapid clearing of the pig-beds by the travelling cranes enables the furnace-man to do all the moulding required for the night by daylight; at the same time the group system is attended by absence of scrap in the beds, and greatly reduces Sunday-work.

II.—Cold-Blast Furnaces.

Some old and some recent practice in this manufacture may be of interest.

No. 1 blast-furnace at Lowmoor was constructed and put into operation over a century ago, the first cast of iron being made in August 1791. This furnace, which will remain in operation only a short time longer, has a height of 42 feet; bosh, 12 feet; hearth, 3 feet 6 inches; throat, 8 feet, and open top. Capacity of furnace, 2600 cubic feet. Coal used as coke, 4 tons per ton of pig iron. Number of tuyeres, 3; diameter of muzzles, $2\frac{3}{8}$; pressure of blast, 2 lbs. per square inch. Production per week, 75 to 80 tons. Old age and infirmity having crept over the furnace, and the minerals in its vicinity being worked out, it became necessary to erect a furnace in a more convenient situation; so last year a new furnace was put into operation. This furnace (Plates III. and IV.) is probably the largest cold-blast furnace yet constructed. It is 70 feet high; bosh, 18 feet in diameter; hearth, 9 feet; throat, 15 feet; bell, 11 feet; capacity of furnace, 10,700 cubic feet.

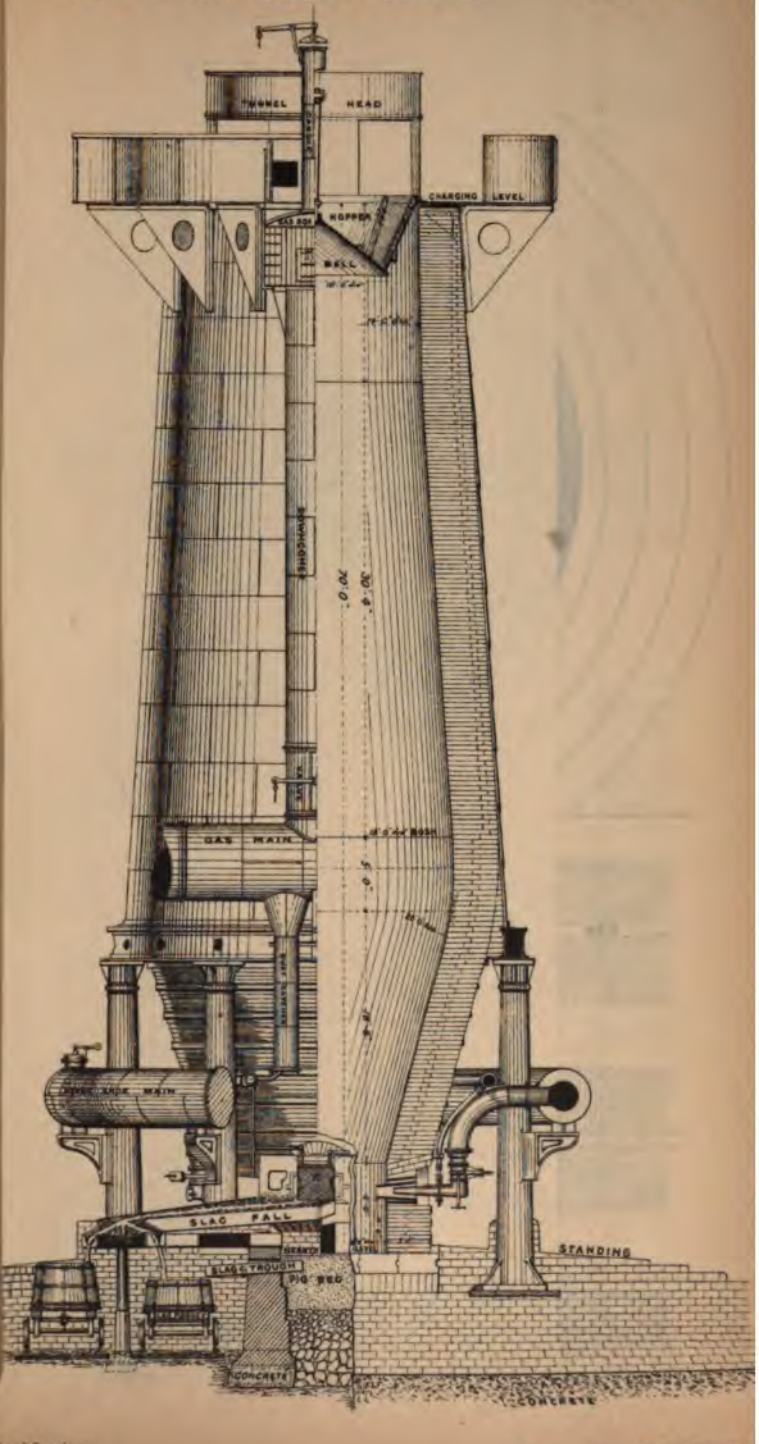
There are two calcining kilns, each 40 feet high and 24 feet outside diameter. The two single high-pressure non-condensing blast-engines are of the vertical direct-acting type, working independently of each other; the steam cylinders, 40 inches diameter, and the air cylinders, 84 inches, both having a 5-feet stroke.

There are four Lancashire boilers, each 7 feet 6 inches diameter, and 80 lbs. pressure of steam.

With one engine at work, making 28 revolutions per minute, 4 lbs. pressure of blast, and 3 tuyeres with 4-inch muzzles, 350 tons per week of grey iron was attained, the quantity of blast at atmospheric pressure was 10,000 cubic feet per minute. The coke per ton of pig iron was 38 cwts.

The Better Bed coal of the district is exclusively used for pig iron making. The seam has an average thickness of only about 22 inches, and as there is a large amount of dirt from the roof and floor, the coal is first washed, then crushed, and in 11-feet beehive ovens makes a hard, bright coke, containing from 6 per cent. to 8 per cent. of ash, and only $\frac{1}{2}$ per cent. of sulphur. The ironstone is directly above, and worked with the Black Bed coal. It contains

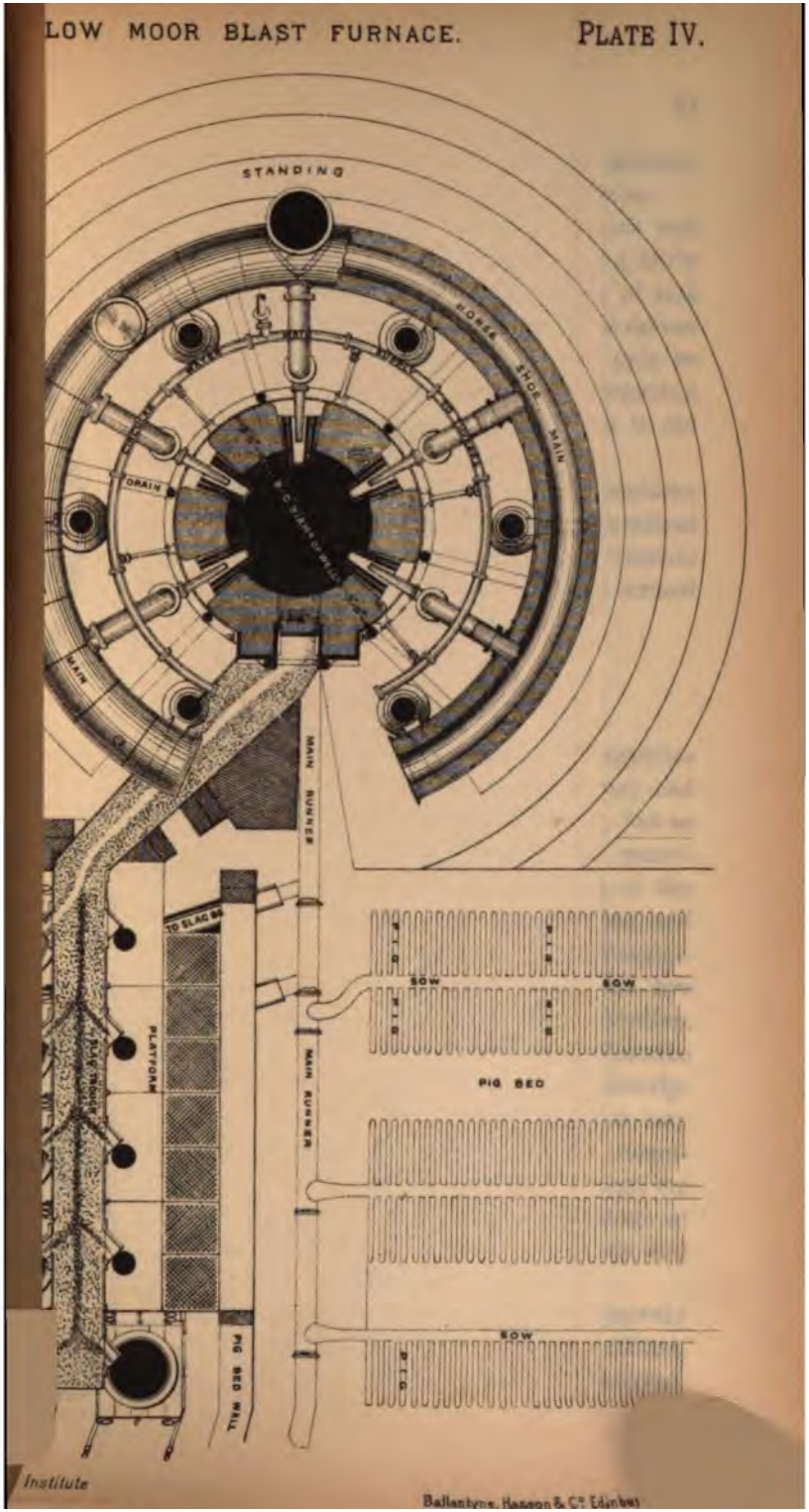
LOW MOOR BLAST FURNACE. PLATE III.



Steel Institute

Ballantyne, Hanson & Co. Edinburgh

LOW MOOR BLAST FURNACE. PLATE IV.



Institute

Ballantyne, Hanson & Co. Edinburgh

in the raw state 30 per cent. of iron, and about 42 per cent. calcined, 3⅓ tons of raw stone being required to make a ton of pig iron.

There is no doubt that a blast-furnace, in order to work well and give a regular quality of pig iron, should be worked at a fairly fast rate of driving; it is also certain that the amount of iron produced depends on the quantity and pressure of the blast driven in. The speed at which a furnace should be driven can only be determined by experiment. The furnace now being described worked far better when making 350 tons per week than it did when making 200 tons.

A second blast-engine was erected, so that in case of accident to one, the other could be made available. Here is an excellent opportunity of ascertaining, under the simplest conditions, whether the best rate of driving has been reached by what might be termed a moderate speed, and advantage will be taken of it.

III.—Manufactured Iron.

The puddler is not yet dead, for we find in last year's statistics of the British Iron Trade Association, that, in spite of very bad trade, the country produced 1,500,000 tons of puddled bars; but so little has been said in this Institute of late years on the manufacture of iron, that it may interest you to hear something of the mode of making a material which has the highest reputation, and which, so far, for certain purposes, nothing has been able to dislodge.

In speaking of best Yorkshire iron, of which there are five manufacturers, Monkbridge, Farnley, Taylor Brothers, Bowling, and Low Moor, I am only able of my own knowledge to describe the process of manufacture at Lowmoor, and as no general description has, I believe, ever been given, I trust the information may be found interesting. As my active connection with the manufacture of iron and steel must, in the natural order of things, ere long cease, you will acquit me of any desire to take advantage of the position you have placed me in, if I describe methods and processes in which I am personally engaged.

Cold-blast pig iron—really *cold-blast*—has always exclusively been made at Low Moor. It contains from 1 to 1¼ per cent. silicon, and 0·3 phosphorus; a very rich grey forge quality is preferred.

The whole of the pig iron is passed through the refining process. There is no pig iron puddled.

The refinery eliminates the whole of the silicon, and reduces the phosphorus to 0·1 by constant practice with materials of very slight variation, the refiner knowing how to leave the carbon untouched. The puddlers, therefore, have only to perform the duty of eliminating carbon, and the small remaining quantity of phosphorus, in order to obtain a practically pure lump of iron. As it is of vital importance that the puddling should be as nearly perfect as possible, and that the shingling under the steam-hammer be equally well performed, rewards and fines are established in order to procure even quality of workmanship.

The method of inspection of the puddled and hammered lump is as follows:—The foreman every day chooses from each man's work any heat he desires to test, and has one or more pieces broken through. The fractures of these lumps are carefully examined, and numbered according to the degree of perfection attained. These numbers are added up at the week-end, the workmen having the most numbers, representing the worst samples in evenness of quality, have to stand out, or, in other words, are not allowed to work on the following week, whilst the men who have the least numbers, representing the best samples of work during the week, are rewarded by money prizes. This system necessitates the keeping of surplus men, who are waiting to be taken in when others are turned out. The decision of the foreman in judging the samples is never disputed. The samples are exhibited, so that the men have every opportunity of examining for themselves the work they produce, the figures showing each man's work being posted up daily, so that the men are satisfied that no partiality is shown, no errors of judgment made. This system has been strictly carried out day by day, and every day over many years, and creates a very desirable competition, keeping the men's attention concentrated on their work.

The puddler works ten heats of refined metal of 3 cwts. each per turn. The puddled balls are all worked under 50 cwts. steam-hammers into slabs about 12 by 10 inches of varying thickness. Each slab bears the puddler's special mark. These slabs are then piled and repiled to make the required weight for rolling into the various

sizes of finished iron, whether plates or bars. All these weldings require the greatest care in heating and hammering; the iron bears a very high heat without any deterioration of quality.

In plate-rolling the greatest care, too, has to be taken to avoid laminations and blisters; the purer the iron, the more difficult it seems to be to prevent them. Careful examination is made when rolling by having jets of water playing on the surface of the plates, to detect blisters or unwelded portions. The inspection is continued when the plate is cold by rapping all over both surfaces with a hammer and noting the sheared edges all round the plates.

The workmen, having inherited their fathers' positions, have done no other work all their lives but manipulate the same class of materials to produce the same results. Only one quality of iron being made, the same methods of working having been pursued over very many years, each workman is especially skilful at his respective task. The result of all this care and skill and good materials is a soft, ductile, and trustworthy iron.

About two and a half centuries ago, Butler, in "Hudibras," canto iii., exclaimed—

> "Ay me! what perils do environ
> The man that meddles with cold iron;
> What plaguey mischiefs and mishaps
> Do dog him still!"

Had he lived in these later years of the Victorian era, how very much stronger would his language have been had he been a manufacturer of iron, with an experience of tensile strains, percentages of elongation, and contracted areas; falling tests, which are no sooner fulfilled than more onerous ones are substituted; hot and cold bendings, ram's-horns, chemical analyses, in which the two-hundredths of one per cent. of a metalloid is cavilled at; the wrangling with workmen and their representatives; the satisfying of Great George Street and other engineers; and last, though not least, the peril which environs the unfortunate manager at the yearly meeting with the justly indignant, dissatisfied, and non-dividend-receiving shareholder.

This leads me to talk of tests, and to make an appeal to those who are not practically acquainted with the manufacture of iron.

Best Yorkshire iron has attained its high reputation by reason

of its power to withstand many sudden shocks without fracture, its reliability, and its welding qualities. The tensile strain that such iron naturally gives, or, as Sir James Kitson better expresses it, "cheerfully gives," should be accepted, when all the processes of manufacture are conscientiously performed by those who value their reputations, and, indeed, whose very existence as manufacturers is at stake.

Some engineers insist on higher tensile strains in iron, when, at the same time, they require fibre to give safety, and softness to give weldability.

Professor Arnold has just made the following interesting experiment. He took 50 lbs. of pure wrought iron and fused it in a special crucible, so as to free the mass from interposed slag; the lump hammered and rolled exceedingly well. It contained iron, 99·76 per cent., and carbon, 0·07 per cent. The mechanical tests gave 21 tons tensile strain in 2 inches; elongation, 50 per cent.; reduction of area, 80 per cent. Now, for mild steel to stand Lloyds' tests of from 28 to 32 tons tensile strain with 16 per cent. elongation in 8 inches we find that for a plate ¼-inch thick the carbon should be 0·15, and for 1 inch thick to stand the same tests, and allowing for the smaller amount of work on the plate, the carbon should be 0·25.

Best Yorkshire iron, on a plate ¼-inch thick, will stand 23 tons tensile stress with the grain 16 per cent. elongation, and 20 tons crossways with 12 per cent. elongation, and a plate 1 inch thick will stand 22 tons with the grain and 16 per cent. elongation and 20 tons crossways, with 12 per cent. elongation, with the carbon something above traces. These examples prove what every one knows, but which is sometimes lost sight of, that to increase the tensile strength the carbon must be increased, and the greater the amount of carbon the greater the difficulty in welding. It is easy to increase the carbon in a molten metal by increasing the quantity of ferro-manganese, but fibre cannot be obtained in this manner, so it follows that by increasing the carbon in iron to obtain higher tensile strengths, its welding properties and the fibrous nature of its texture are destroyed, giving a harder and more brittle metal, unsuitable for the work that soft iron is called on to fulfil, and to be even dangerous under certain conditions in proportion as the tensile strengths, or in other words, as the carbon is increased.

IV.—Siemens-Martin Furnaces and Plate-Rolling.

Large numbers of open-hearth melting furnaces have been constructed throughout the country during the last ten years. In 1880 there were 126 furnaces, producing 251,000 tons of ingots a year. In 1890 the number had increased to 320 furnaces, producing 1,564,200 tons. The number increased in 1892 to 359, and is still increasing, and new installations of magnitude are being rapidly pushed forward in spite of the fact that there is not half enough work for those already constructed.

The capacities of furnaces have been gradually increased, until some have given as much as forty tons of steel at a cast, but a more manageable and convenient size for all-round work, is one of a capacity of from twenty to twenty-five tons.

The construction and form of the furnace itself is generally much as it was left by Sir William Siemens.

A valuable improvement was made by Mr. James Riley, in conjunction with Mr. Dick, when he separated the regenerative chambers from the furnace. At Blochairn, a furnace of twenty tons capacity, with regenerators so separated, was stopped, the four chambers cleaned, and the gas put on again in three days, which, in the old arrangement, would have required at least fourteen days. This feat is confirmed by the practice at Eston, and is a most important consideration with such costly plant and labour. A useful and good practical detail is a trap arrangement outside the chambers for catching dust, and the drippings from the ports and uptakes, which choke up the chequer-work; this trap can be quickly cleaned, so that the furnace is kept longer at work, and makes much more steel before requiring general cleaning and repairs.

But the boldest and most successful improvement in the general arrangement of handling and dealing with the molten metal till it is converted into a finished plate, without reheating the ingot, was devised and carried out by Mr. Riley some few years ago, and as I and others have benefited by his ideas, he should have the credit due to his skill and pluck. The arrangement has not since been much, if at all, improved, and I therefore venture to briefly describe it.

A range of some dozen 18 tons open-hearth furnaces at Blochairn, all in one line, and having the usual casting-pit in front of each furnace, the ingots and moulds being handled by a steam travelling crane, the men working in a hot, stifling atmosphere, was changed to an arrangement whereby the molten metal is received in a travelling ladle from each furnace, and then conveyed by a locomotive to a central and convenient position, where the operation of teeming the ingots is conducted in comparative comfort. When the ladle of molten metal arrives at its destination, it is lifted off its trunnions by a hydraulic apparatus, and the metal re-poured into a second ladle, mounted on a hydraulic centre casting crane of 20 feet radius, the object of the re-pouring being to obtain a uniform steel by the more thorough combination of the alloys of carbon, manganese, and iron.

The ingot moulds of varying sizes, to hold up to as much as 8 tons of metal, are placed round the circumference of a shallow casting pit in the usual manner, except that the larger end of the ingot mould is uppermost, the object being to give greater density to the smaller end of the ingot, which receives the least amount of work under the steam-hammer or cogging machine, and to put most work on the upper part, which has the greatest need of it.

In order to be able to grasp the ingot for withdrawal from the mould, there are two pieces of iron at the sides of convenient size, easily removable when the ingot is sufficiently cooled to be lifted out, which, in the largest ingots, requires about forty minutes.

The ingots, which are usually about 4 feet long, 3 feet 6 inches wide, and 20 inches thick, are then lifted out of the moulds by quick-acting hydraulic cranes, placed in Gjers' soaking-pits, and left there about two and a half hours in order that the heat may have time to equally diffuse itself throughout the mass.

Mr. Riley passes all the ingots produced, nearly 300 tons per shift, through soaking-pits, not finding the least difficulty even with those made in the first cast on a Monday morning, after stopping work on the Saturday. The ingots are then conveyed by simple and effective mechanical arrangements to the cogging-mill, where by successive to and fro passes the ingot is reduced to a slab of a thickness suited to the plates into which it is afterwards to be rolled, and cut up under a very powerful hydraulic shears,

provided with easily and quickly adjusted stops, to permit the slabs being cut to the required varying sizes with the least amount of waste of material. The slabs are so cut that the crossways of the grain in the slab becomes the lengthways of the grain in the finished plate. They are then conveyed by mechanical means to the reheating furnaces, and rolled either in a two-high reversing train or in a three-high mill, having the centre roll of smallest diameter. It is a moot-point as to which of these two systems of plate-rolling is the better, both being so good. It may perhaps be decided by giving the preference to the two-high systems for very heavy plates, and to the three-high for ordinary sizes.

V.—Bessemer Converters and Rail-Rolling.

The largest production of ingots, 2,140,000 tons, was obtained in 1889, and the largest output of rails, 1,235,785 tons, in 1882.

Although there are 108 Bessemer converters in the country, only 1,510,810 tons of ingots and 535,836 tons of rails were made last year.

The steel trade being even in a more stagnant position this year than it was last year, there is no scope for the energy of our steel-makers, and they are unable to show any satisfactory results of output, or any great improvement in construction or arrangement of plant. In fact, with the exception of greatly increased production by the elimination of causes of delay, by improvements in making and rapidly changing the converter bottoms, and the adoption of a shallower casting-pit, the whole apparatus for ingot making is much as it was left by Sir Henry Bessemer.

For some years past large quantities of molten iron have been taken direct from the blast-furnaces to the converters, in order to avoid the cost of remelting in cupolas.

With all our knowledge of blast-furnace working, we are unable to obtain a uniform quality of iron.

By the older method of remelting, pig iron from several casts was spread over a large surface in stock in such a manner that, when taken out again, it was so equalised in quality that no great inconvenience was experienced through variations in the length of blow or in the quantity of additions of scrap, but ladles of iron taken direct from the blast-furnaces sometimes varied considerably,

more especially in the percentage of silicon, and if it is attempted to make iron low in silicon, the increased percentage of sulphur becomes a serious trouble.

The iron has often been taken from two or more furnaces, but it is found troublesome to have to tap two furnaces for eight or twelve tons of metal, and then only obtain partial relief from a difficulty.

Captain Jones carried out an idea of constructing a reservoir termed a "Mixer," which would hold about 100 tons of molten metal, with the view of equalising the quality of the iron used by mixing iron from several furnaces and from several casts.

Two mixers, which hold about 150 tons each, have been constructed at Eston, and have given greatly improved results.

The iron from the blast-furnaces varied in silicon to the extent of $1\frac{3}{4}$ per cent., the highest percentage being 3 and the lowest $1\frac{1}{4}$, the average giving 2 per cent. of silicon from the mixer; the lowest percentage from the mixer being 1·95 and the highest 2·15. The result of this mixing is that the length of the operations in the converters, and the amount of scrap used, become almost uniform, thus increasing the life of the converter linings and bottoms to a considerable extent, giving steel regular in carbon, and thereby reducing the percentage of defectives. At Eston the mixer has been found even more valuable in the basic than in the acid process—enabling iron low in silicon to be used. Sulphur can be reduced 50 per cent. by addition of manganese. The converter linings and bottoms last 30 per cent. longer, the quality of the steel made being practically uniform.

To illustrate what can be done in a steel plant, I have selected the comparatively small works at Scranton rather than one of the colossal establishments of our own country.

The works I am able to describe, through the courtesy of my old friend Mr. W. W. Scranton, were erected by him at Scranton, Pennsylvania, after a visit to this and other countries for the purpose of ascertaining the latest improvements that had been carried out in Bessemer steel-making, and, as he decided to adopt the system of rolling then in operation at Bolckow, Vaughan, & Co.'s, I feel great interest in this plant, though not alone for that reason, but more because of the splendid results achieved by the energy,

ability, power of organisation, and systematic management of Mr. Scranton.

I will describe the plant very briefly, as I have permission to place before you in an appendix a fuller description of the whole works.

The machinery was first designed for an output of 60,000 tons of steel rails per annum, that quantity being obtained from the outset. In the spring of 1890 the pair of so-called three-ton Bessemer converters was replaced by a pair of six-ton vessels, when the following remarkable results were achieved:—Taking the three months from March 1 to May 31, 1890, the *average* weekly production of ingots was 5005 tons; the best week's work was 5456 tons in twelve turns, and the poorest was 4417 tons in eleven turns.

The best day's result was 1012 tons, and the best twelve hours work 518 tons.

The number of heats blown was 61,154, and the time required to blow a heat was twelve minutes; quite frequently two heats were blown at the same time.

The converter bottoms have nineteen tuyeres 24½ inches long, with specially shaped bricks to fill the spaces; each tuyere has nineteen $\frac{5}{16}$-inch holes. There were 374 bottoms used during the above-mentioned period, the average life being 25·34 heats.

The blast is supplied by two pairs of horizontal engines having 50 inches steam-cylinders and 54 inches air-cylinders, and 5 feet stroke, running between 30 and 40 revolutions per minute, the pressure being seldom below 30 lbs. per square inch at the engines. There are nine re-melting and three spiegeleisen cupolas.

The ingots are quickly conveyed, as hot as possible, by small 2-feet gauge locomotives, to ordinary heating furnaces fired by anthracite pea coal, provided with fan-blast; each furnace holds eight ingots, two by each door. The roll trains consist of three sets of rolls, each 32 inches in diameter. The blooming and roughing rolls are worked by a pair of reversing engines on Ramsbottom's system, having cylinders 40 inches in diameter by 5-feet stroke, geared two to one. The ingots, 14½ inches square at the bottom and 13 inches at the top, are rolled into rails in fifteen passes, six in the blooming, four in the roughing, and five in the finishing rolls.

In the rail-mill the average weekly production was 4330 tons —the best was 4674 tons in twelve turns, and the poorest 3865 in eleven turns—the largest tonnage per day was 883 tons, the largest per turn 460 tons of 60-lb. rails.

In the six months ending June 30, 1890, the make was 117,100 tons of ingots and 101,143 tons of rails.

In the autumn of 1890 the two 6-ton converters were changed to a pair of 10-tons, and even then there was not a sufficient supply of ingots to keep the rolling-mill fully at work, but in twelve hours 1774 rails weighing 554 tons were produced in a mill driven by a pair of reversing engines having 48-inch cylinders, and 54-inch stroke, coupled direct to the roll train, and making from 90 to 100 revolutions per minute.

These are results of which any manager may be proud. The American steel-works have so largely increased production, that even that large country is not large enough to supply sufficient occupation for the existing works. But it must not be thought that because I have described an American plant I consider our own country behindhand; quite the contrary, but I fear to describe our capabilities and latent power of production.

All those who manage steelworks, either for the production of rails or ship plates, pride themselves on their power of organisation, not only to increase output, but to maintain high quality.

Then, again, the ingenuity of our engineers has been called into play to substitute mechanical arrangements for the so-called cheap labour. One cannot fail to observe how few men are employed in a mill turning out 5000 tons of finished rails weekly. The heavy ingots are conveyed by small locomotives to the rolling-mills, are moved to and from the several grooves of the rolls by live rollers, are turned over and carried sideways, rails are rolled in 155 feet lengths, are carried to the saws, are cut, are conveyed away, are placed on hot banks to cool, all by ingenious mechanical contrivances. The same may be said of plate-rolling.

It is only when the material becomes cold that labour becomes expensive and troublesome; but the more difficult it becomes the surer will machinery be devised to dispense with it.

So successful have we all been in economically increasing production that we have inundated and swamped the markets for the

time being; at present, and for some time past, there is not enough work for half the steel-producing power of the country.

Thus we go on, and we look about in vain for new markets. We compare America with 60 millions of people, having 175,000 miles of railway, with India having 250,000,000 of people, and only 17,000 miles of railway, and wonder why, under our sway, it develops at such a wretchedly slow rate.

Where is the trade to come from to keep our workmen employed and our establishments in operation? No one seems to be able to answer this question; but we know that we have had many serious depressions before, though none seem so deep, so prolonged as this.

The iron and steel trades may be likened to Pandora's box, from which, once filled with all good things and all bad, everything escaped—the good things back to heaven, and the evils to infest and plague the earth; but there is still left to us that which never deserts us, the inestimable blessing—HOPE.

APPENDIX.

THE WORKS OF THE SCRANTON STEEL COMPANY, PENNSYLVANIA.

THE plant of the Scranton Steel Company was originally designed for an annual output of 60,000 tons of steel rails. It consisted of two 3-ton converters and four pig iron cupolas. The first rail was rolled in May 1883, and the anticipated capacity of the works was at once exceeded. In the spring of 1890, when the original 3-ton converters had long been replaced by a pair of 6-ton converters, the efficiency of the plant far exceeded the most sanguine expectations of its originator, Mr. W. W. Scranton. In the autumn of 1890 the 6-ton converters were replaced by a pair of 10-ton converters, and on January 1, 1891, the works were consolidated with those of the Lackawanna Iron and Coal Company into a new undertaking, the Lackawanna Iron and Steel Company. Mr. Scranton then gave up the personal management of the plant, and became one of the board of directors of the new company.

The accompanying table (pp. 32, 33), compiled from the books of the Company, records the results achieved by the plant from Saturday March 1 to Saturday May 31, 1890:—

SCRANTON STEEL COMPANY.

PRODUCTS OF STEEL WORKS AND RAIL MILL FOR A PERIOD OF THREE MONTHS.

(Average weight per heat, 688 tons.)

Date.	No. of Heats.	Ingots.			Rails.															
		No.	Weight.		60 Lbs. (3 Patterns).			60½ Lbs.			63½ Lbs.			65 Lbs.			67 Lbs.			
					No.	Weight.		No.	Weight.		No.	Weight.		No.	Weight.		No.	Weight.		
1890.			Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.	
Saturday, March 1	27	162	185	6	674	180	10	...	...	...	...	...	...	...	...	...	...	...	...	
Week ending Mar. 8	805	4,441	5,456	15	2,651	710	2	...	...	...	...	...	...	...	...	...	...	...	...	
Do. do. 15	764	4,564	5,230	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Do. do. 22	723	3,879	4,906	13	1,192	319	5	...	...	...	404	114	10	...	...	...	...	...	...	
Do. do. 29	730	4,320	4,934	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Do. Apr. 5	762	4,412	5,179	...	872	233	11	...	...	...	...	...	...	...	...	...	2,610	780	13	
Do. do. 12	696	4,125	4,812	4	7,561	2,025	7	...	...	...	...	...	...	...	...	...	346	103	9	
Do. do. 19	754	4,365	5,192	2	10,091	2,702	19	...	...	...	...	...	...	...	...	...	607	181	11	
Do. do. 26	700	4,186	5,030	9	2,794	748	7	...	...	...	...	...	...	5,453	1,582	8	...	...	...	
Do. May 3	731	4,301	5,079	17	...	...	...	...	...	...	...	...	...	...	...	...	2,002	598	16	
Do. do. 10	747	4,470	5,214	18	...	...	...	3,819	1,031	9	...	...	...	...	...	...	...	...	...	
Do. do. 17	734	4,111	5,013	9	93	24	18	4,110	1,110	1	...	...	...	...	...	...	5,214	1,559	11	
Do. do. 24	646	3,859	4,447	16	5,814	1,557	6	...	...	...	...	...	...	...	...	...	...	...	...	
Do. do. 31	660	3,938	4,569	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	9,479	55,133	65,253	2	31,742	8,502	5	7,929	2,141	10	404	114	10	5,453	1,582	8	10,779	3,224	...	

SCRANTON STEEL COMPANY.—*Continued.*

Date.	Rails.																					
	68½ Lbs. (2 Patterns).			70 Lbs.			72 Lbs. (2 Patterns).			76 Lbs. (2 Patterns).			78 Lbs.			80 Lbs. (2 Patterns).			Total No.	Total Weight.		No. of Turns.
	No.	Weight.		No.	Weight.		No.	Weight.		No.	Weight.		No.	Weight.		No.	Weight.					
1890.		Tns.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.		Tons.	Cwt.	
Saturday, March 1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	674	180	10	1
Week ending Mar. 8	...	...	...	6,830	2,134	7	...	...	...	...	...	...	...	...	...	5,124	1,830	...	14,605	4,674	9	12
Do. do. 15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12,860	4,592	17	12,860	4,592	17	12
Do. do. 22	343	104	17	...	...	...	7,900	2,539	8	1,904	646	...	...	...	...	1,479	528	4	13,222	4,252	4	12
Do. do. 29	334	102	2	...	...	...	355	114	2	4,660	1,581	1	...	...	...	7,039	2,513	19	12,388	4,311	4	12
Do. Apr. 5	...	...	...	...	...	...	...	...	...	2,233	757	12	...	...	...	7,675	2,741	2	13,390	4,512	18	12
Do. do. 12	...	...	...	365	114	1	...	...	...	...	...	...	...	...	...	5,564	1,987	2	13,836	4,229	19	12
Do. do. 19	...	...	...	2,034	635	12	...	...	...	...	...	...	...	...	...	2,766	987	17	15,498	4,507	19	12
Do. do. 26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,268	1,881	8	13,515	4,212	3	12
Do. May 3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9,647	3,802	10	11,649	4,401	6	12
Do. do. 10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9,893	3,533	4	13,712	4,564	13	12
Do. do. 17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4,323	1,543	19	13,740	4,238	9	12
Do. do. 24	...	...	...	...	...	...	1,136	365	2	...	...	...	...	...	...	5,440	1,942	18	12,390	3,865	6	11
Do. do. 31	...	...	...	...	...	...	...	...	...	...	...	...	2,971	1,034	10	8,108	2,895	15	11,079	3,930	5	11
	677	206	19	9,229	2,884	...	9,391	3,018	12	8,797	2,984	13	2,971	1,034	10	85,186	30,780	15	172,558	56,474	2	155

Steel rails, 50 lbs. per yard and upward, sold and shipped from January 1, 1890, as reported by Board of Control, to July 1, 1890:—

	Tons.
1. Illinois (Union, Joliet, and North and South Chicago combined)	197,207
2. Carnegie's (four 10-ton converters)	154,931
3. Scranton (two 6-ton ,,)	101,143
4. Lackawanna (three 8-ton ,,)	74,473
5. Bethlehem (four 8-ton ,,)	70,187
6. Pennsylvania (five 8-ton ,,)	62,469
7. Cambria (two 8-ton and two 10-ton converters)	52,795
Total	713,205

The waste in the cupolas did not exceed 4 per cent.; a good deal of iron, which would otherwise have been lost, was saved by the aid of a rumbler and a magnetic separator. The average loss in the converters amounted to 8·80 per cent., inclusive of scrap afterwards recovered. The actual loss in the converter was about 4 per cent. The pig iron used yielded an excellent quality of steel, containing 1.5 to 4 per cent. of silicon. The proportion of phosphorus was low, but that of sulphur occasionally reached 0·2 per cent. It also contained a considerable amount of copper, the proportion varying from 0·75 to 1·05 per cent. This element, in combination with sulphur, proved to be somewhat troublesome at the rolls, but the difficulties were soon overcome. In this connection it may be noted that at these works Lebanon (Cornwall) pig iron was first successfully used on a large scale. It contains 0·8 to 1·0 per cent. of copper, with a very irregular proportion of sulphur. It is a hard pig iron to work, and requires close watching, but it renders the steel extraordinarily tough.

The proportion of combined carbon in the steel was very uniform, the variation being from 0·38 to 0·45 per cent. The silicon varied from 0·055 to 0·078 per cent., the sulphur from 0·06 to 0·074 per cent., the manganese from 1 to 1·20 per cent., the copper from 0·6 to 0·7 per cent., and the phosphorus seldom exceeded 0·065 per cent. The average ultimate strength was found to be 99·492 lbs. per square inch, the lowest result recorded being 93·800 lbs. per square inch, and the highest 104·300 lbs. per square inch. The limit of elasticity was 67·060 lbs., and the elongation 11·3 per cent.

The plant is compact, and the buildings are plain and strong. Concrete was used in many of the heavy engine foundations. This is probably the first time that this material was employed in America for such purpose.

The Bessemer works consist of a complex of brick buildings, with strong iron roofs covered with heavy corrugated galvanised iron. The cupola building, which is 72 feet 8 inches wide, 91 feet 5 inches long, and 45 feet 9 inches high from the general floor level to the lowest part of the roof trusses, has three iron floors—the ladle, tapping, and charging floors—11, 20, and 36 feet high respectively. There are nine cupolas for the melting of Bessemer pig iron, three spiegeleisen cupolas, two elevators, four Baker blowers connected directly with two steam-engines, 18 inches by 24 inches, averaging 100 revolutions per minute, and, lastly, two hot-metal scales, one for Bessemer pig iron and the other for spiegeleisen. From the scales, the ladles, mounted on trucks and propelled by a small locomotive, pass in a direct line to the front of the converters. Only four pig iron cupolas and one spiegeleisen

cupola are in operation at the same time, a fresh pig iron cupola being put on every twelve hours. The iron cupolas have 9-feet shells, and are provided with discharging doors, with four openings for charging on the floor level, with two slag spouts and with ten oval tuyeres, 9 by 6½ inches, placed 4 feet above the base, and supplied by 24-inch blast pipes. Their inside diameter is 88 inches, contracting to 80 inches at a point 7 inches above the tuyeres, and from there on down to the bottom. The fuel used is lump anthracite. The blast pressure is from 12 to 18 oz. per square inch.

The spiegeleisen cupolas have 5-feet shells, and are provided with discharging doors, with one opening for charging on the floor-level, with one slag spout and with six oval tuyeres, 4 by 6 inches, placed 3 feet 6 inches above the base, and supplied by 15-inch blast-pipes. Their lining is straight from the charging-floor down to the bottom, and measures 40 inches in the clear. The fuel and the pressure of blast are the same as for the iron cupolas.

The elevator platforms are 7 feet 4 inches square. They are driven by vertical 12-inch hydraulic cylinders, with 18 feet stroke, and geared one to two by means of pulleys and ropes.

The balance of the blast required for the cupolas is derived from six additional Baker blowers, connected and driven in same manner as those above, two of them being placed in a brick wing adjoining the converter-house, and four in a separate brick building. The capacity of each blower is 7200 cubic feet of air per minute.

The converter-house, which measures 72 feet 6 inches by 116 feet 9 inches, with a height of 31 feet 9 inches to the bottom of its truss chords, is connected with the cupola-house. The converter platform is really an extension of the cupola ladle floor, 11 feet above the general level. The operating pulpit is also on this same floor, conveniently situated at the junction of the two buildings. Longitudinally the two converters occupy a central position, but laterally they are situated close to the side of the main building which opens into the bottom house. The converter platform extends in this building for a distance of 14 feet.

The converters were originally designed for 6 tons, and did the best and heaviest work at about that weight, but, as may be seen in the accompanying table, they were crowded at times well up to 7 tons. Though the product was greater at the heavier weight, yet the waste was greater also. However, at some prices, greater product, even with increased waste, would be better than less product and less waste. Financial considerations outweigh mechanical ones.

The converters have an outside diameter of 7 feet 10 inches; inside

the lining they measure 6 feet. They are heavy structures for their size, each weighing 15 tons without and 32 tons with the lining. The centre of their 18-inch cast iron trunnions is 15 inches above the platform, and 4 feet above the top of the tuyeres. The trunnions are hollow, the core on the side where the blast enters being 9 inches. The converters are operated by means of 15-inch hydraulic cylinders, working horizontally on the sides of the beams supporting the converters. The racks and pinions are made of steel. The noses are slightly inclined; their smallest diameter is 24 inches in the clear, and the medium distance from the top of the tuyeres is 12 feet. Behind each converter, in an adjoining building, already referred to as the bottom house, 43 feet 7 inches wide, 55 feet long, and of the same height as the converter house, there is a stack, 8 feet shell lined with 4-inch bricks, the top of which is 50 feet above the general level, and the lower part provided with a hood reaching into the converter building. On one side of each stack, directly underneath it, there is a crane, and on the other side, attached to the hood near the converter, a small crane for handling the blast box covers.

The converter bottoms are made up with nineteen tuyeres, 24½ inches high, and special shaped bricks to fill in between. Each tuyere has nineteen $\frac{5}{16}$ holes. The bottoms are manipulated on a truck, moving on rails under the converters, and provided with a 12-inch hydraulic lift of 16-inch stroke.

Iron trucks come in on the same rails to receive the converter cinder after each heat. The bottoms are prepared in the building above mentioned, and handled by means of a 13-inch hydraulic crane of 9 feet lift. On each side of this building there is a wing 37 feet 6 inches wide and 55 feet long. In one of these wings, divided in two sections, there are in the first section the two Baker blowers already mentioned, with a steam-engine 18 inches by 24 inches, and in the other a pulverising mill and a stone crusher driven by an engine 12 inches by 20 inches. The second wing is divided into five parts—one stopper room, one stopper oven, and three ovens for the converter bottoms. In the main building, in front of the converters, there is a casting pit, 4 feet deep, in the shape of a semicircle, the radius of which is 19 feet, and a hydraulic ladle or casting crane with a 20-inch plunger, having a lift of 5 feet 6 inches. This pit holds moulds for four heats, and is commanded by two 10-ton hydraulic fast-working ingot cranes of 18 feet swing, provided with hydraulic motors for every movement. The ingots are stripped in the pit, three of the moulds taken out at the same time by means of these cranes quickly turned over to an apparatus tipping them in a horizontal position on iron trucks, which are imme-

diately taken out in the yard to cool, where a system of sidings and switches is provided especially for this purpose. The ingots are then loaded on to trucks in readiness on rails situated directly in front of the pit, and without delay forwarded to the rail mill.

New or cooled-off moulds are brought back in front of the tippers, of which there is one to each crane, and from there, two by two, transferred to the pit for the next heat in a remarkably short time. The steel ladles are prepared, stored and dried on four stoves fired with culm or coal dust in the same building, on one side of the converters opposite the cupola-house, and handled by means of a 13-inch hydraulic crane.

The blast for the converters is furnished by two horizontal twin blowing engines, each pair being provided with a fly-wheel of 25 feet diameter, weighing 100,000 lbs. Steam is worked expansively during $\frac{2}{5}$ of the stroke, and the exhaust steam passes through large heaters, thereby heating the feed water for the boilers. The water passes into boilers at an average temperature of 200° F. Poppet valves for the steam, placed on the side of each cylinder, are worked by cams and levers, whose motion is obtained from a shaft, parallel with the axis of the cylinders, and from a pair of mitre wheels driven by the main shaft. The inlet and outlet valves of the blowing cylinders are automatic and of the plate type, well guided and provided with suitable steel springs. The steam pressure varies between 60 and 80 lbs.; the pressure of blast is about 30 lbs.

These engines are specially adapted for their work; they are strong, efficient, and much admired. Situated in this same building there are two Worthington duplex pressure pumps, 29 by $9\frac{1}{2}$ by 36; one do. (improved pattern), 29 by 9 by 36; two Knowles' duplex pressure pumps, 30 by 10 by 36; two Knowles' feed pumps, 30 by 16 by 24; two 21-inch accumulators, 15 feet lift, with open plungers and consequent air cushions. One No. 37 Sturtevant fan blower, driven by an engine 12 by 20, producing blast for the heating furnaces in the rail mill; and finally, mounted in iron columns, a steel tank 23 feet 2 inches long, 11 feet wide, and 8 feet 6 inches high, into which the water from all the hydraulic motors of the plant returns, to be used again in the pressure pumps. With this arrangement the hydraulic motors always remain filled, and a small back pressure is obtained, causing smoothness in their operation.

Adjoining the engine house, in a frame building 52 feet wide, 512 feet 4 inches long, and 20 feet high, well ventilated and covered with slate, there are six Berryman feed water heaters, 52 inches diameter, 22 feet high; two large water traps or steam separators, and 54 loco-

motive boilers fired with culm, heaped up in large quantities in close proximity of the works. The Scranton Company was the first in the United States to use *culm* (anthracite waste) on a large scale, and had to experiment for some time before they discovered the method of using it satisfactorily. It is now used all through the region.

Twenty-four of the original boilers are made of iron; their outside diameter is 54 inches; they each contain 116 3-inch flues 16 feet long, and have 24-inch smoke flues, and a grate surface of 33 square feet. The other boilers, thirty in number, are made of steel and slightly larger. Their outside diameter is 60 inches; they each contain 81 3½-inch flues, 15 feet 6 inches long, and have 30-inch smoke flues, and a grate surface of 40 square feet. There is one fireman to every three boilers. All the boilers are put up in nests of three connected with a 60-inch iron stack, 180 feet high from the general level, measuring 52 inches inside of the brick lining. They are well provided with M'Clare's steam blowers and rocking grates, which are especially well adapted for culm-firing, and from which the whole fire may be emptied in the ashpit in a few seconds. The ashes are tipped directly into trucks on rails behind the firebox, and beneath the boilers, 7 feet below the general level. The aggregate heating surface of these boilers is 69,303, and the grate surface is 1,992 square feet. The main steam pipe is of cast iron, 24 inches inside diameter. All the pipes, as well as the boilers, are covered with asbestos packing, and the safety valves blow off at 80 lbs.

The rail mill on its southern end, joined to the converter house, consists of several wooden frame structures, very substantially built and properly strengthened with iron fittings. Most of the buildings are covered with slate, a few with tin, and the inferior parts all painted with asbestos or fire-proof paint. The extreme length of the rail mill from north to south is 707 feet 8 inches, and the largest truss in the finishing department over the hot-bed has a span of 87 feet 6 inches. The mill is equipped with six heating furnaces, which are simply large old-fashioned furnaces, into which are charged eight ingots at a heat, two to each door. An equal number of 9-inch hydraulic cranes for drawing and charging, one train of rolls served by two reversing engines, one 9-inch hydraulic crane conveniently heated on the roller side of the crane, used for handling parts of machinery in case of repairs or hot blooms in case of an accident at the rolls, three 10 by 10 inch reversing engines driving all the feed rollers; two hydraulic manipulators, one on each side of the blooming rolls; one 20-ton travelling crane for changing rolls operated by a vertical engine 9 by 9; one 40-ton guillotine hot shear, used for cutting off the sand

ends of all the blooms after the third pass in the roughing rolls; one single saw arrangement driven by a 12 by 20 engine; three roll lathes, one cold shear, one cambering machine operated by the saw engine, one 10 by 10 reversing engine for shifting the rails on the hot-bed, one 30 by 150 feet hot-bed, two 12 by 20 steam engines giving motion to the roll lathes above mentioned, to eight straightening presses, and to twelve drilling and two notching machines; one engine 12 by 12 inches, driving two additional straightening presses and two extra drilling machines; one high speed Porter Allen cold saw engine 11½ by 20 inches, and one cold saw.

The furnaces are fired with anthracite pea-coal, and provided with blast from a fan already mentioned, entering through an aperture of 14 inches.

The grates are 7 feet wide and 4 feet long; the interior width of the furnaces is also 7 feet, and the sizes between the plates 9 and 27 feet. Each furnace is supplied with four charging doors for the ingots. The waste gases pass through a short flue 24 by 24 inches into an iron stack 50 inches diameter, the top of which is 71 feet 6 inches above the grate. Inside of the brick lining these stacks measure 36 inches.

The roll train consists of three sets of rolls, 32 inches pitch diameter. Blooming and roughing rolls are driven by a pair of English reversing engines, 40 by 60, built by Davy Brothers at Sheffield and geared one to two. These engines are worked at the rate of 100 revolutions per minute, equivalent to 50 revolutions at the rolls; the ingots measuring 14½ by 14½ at the butt end, 13 by 13 at the top end, and proportionately more if they are shorter, are despatched from the furnaces to the feed rollers in front of the rolls by a small locomotive on a truck running over rails of 2 feet gauge. The body of the blooming rolls is 74 inches long and has four grooves. The operation began with a 13-inch ingot and 21 passes, 8 blooming, 8 roughing, and 5 finishing. They soon came down to 13 passes, 4 blooming, 4 roughing, and 5 finishing. In order to obtain a short ingot, it was made 15 inches (nominally 14½ inches) and rolling continued in 13 passes. But Mr. Scranton found this was too hard on the blooming engine, breaking several cogging wheels, so he put 6 passes in the blooming mill, leaving 4 roughing and 5 finishing, a practice which the mill still maintains; 13 passes, however, would be easy enough with strong engines. It will be seen that it is easy to have three ingots (12 rails) rolling at one time, and thus work very rapidly. It was not difficult to roll sixty to seventy tons of 70-lb. rails per hour. The best 12-hour turn of the mill was made after the two

6-tons converters were taken out in the autumn of 1890, and
10-tons put in. The results were as follows:—

Weight of Rails.	Number of Bars.	Weight.
70 lbs. per yard.	1730	540·12
70 lbs. per yard.	1774	554·70
75 lbs. per yard.	1687	564·16
76 lbs. per yard.	1624	551·00
76 lbs. per yard.	1708	579·10

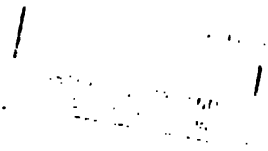
Top end first, the ingot goes through the first groove of the b
rolls, and is reduced to 11¾ inches one way; on the catcher si
quickly turned over by a hydraulic manipulator, shifted back
with the first groove, and after its second pass through this
reduced to a square 11⅜ by 11¾ inches. Shifted sideways
manipulator on the roller side, in front of the second groove,
makes its third pass and reaches the catcher side reduced to 11
After similar manipulations to the first one, it goes back thro
second groove, making its fourth pass, and reaches the rol
9¾ by 9¾ square. Shifted to the front of the third groove
makes the fifth pass, and is reduced to 9¾ by 7⅝ inches. Tu
by the manipulator, the bloom has arrived in front of the
and last groove, through which it makes its sixth pass, and is d
on the feed rollers of the roller side, measuring 7⅝ by 7¾.

Better work than this has been successfully attempted and pe
in this part of the mill. With rolls turned purposely, the san
ingot was brought down to the same dimensions, also in four
but in four passes only. The ingots after the first pass m
14½ by 10¾, after the second pass 10¾ by 10¾, after the thi
10¾ by 7⅝, and after the fourth pass 7⅝ by 7¾, being the
above. In the fear, however, that such immense reductions w
detrimental to the rolls and the engine, this practice was relt
abandoned after using it over a year.

The roughing rolls, as already intimated, are coupled directl
blooming rolls. Their body, in which 4 grooves are turned, is 8·
long. The manipulator on the roller side brings the bloom in
the first pass in which the forming begins. The bloom is then
turned by hand after the first and second pass. On leaving th
pass it moves on to the guillotine shear, where the top or sand
cut off: the piece is then quarter turned once more, and now r
make its fourth pass through the roughings, arriving at the rol
with a sectional area between 16·78 and 17·90 square inch
properly shapped for flanged rails between 52 and 80 lt

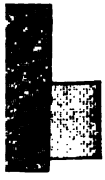


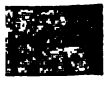


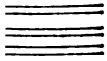












width across the flange and the height of such rails varying between 3¼ and 5 inches.

The body of the finishing rolls is 63 inches long, and contains 5 grooves, in which all of the above-named sizes are finished. The rolls are coupled directly to a reversing engine 48 by 54, built by Davy Brothers at Sheffield, and moving at a speed of from 90 to 100 revolutions per minute. All the rolls are made of the best obtainable iron. After about 1887 we made our blooming rolls of steel, open hearth castings; the rolls turned according to carefully prepared figures and drawings in the mill itself. No shape, however hard to roll, has ever been missed, nor has a new set of rolls ever been taken out for correction. 32·255 tons of rails have been rolled in one pair of finishings, and 5622 tons have been the best result from one dressing.

All the rolls are stored in a frame building 41 by 101 feet, situated at the northern end of the mill, on iron stands holding two sets each. An overhead hand-power travelling crane of 25,000 lbs. capacity, facilitates the handling of the rolls, and insures quick and safe action.

A small foundry, a small machine shop, a blacksmith's shop, a carpenter shop, and a rumbler house in the yard, some distance away from the mill, all well equipped—and a number of coal shoots beneath overhead trestles, coming in between the foundry and the pattern shop, not yet mentioned, from an adjoining coal mine, complete the plant.

The accompanying diagram (Plate V.) represents the ground-plan of the works.

VOTE OF THANKS.

Sir JAMES KITSON, Bart., M.P., proposed, "That the best thanks of the Iron and Steel Institute be and are hereby presented to the President, E. Windsor Richards, Esq., for his admirable and instructive address." Having recently experienced the difficulty of finding new subjects and new matter to present to the Institute in the form of a Presidential address, he could sympathise with the new President, and he could also congratulate him on behalf of the members on the very able and remarkable address which he had just presented to them—a practical address which he had almost made poetic by the elegant language in which he had described the details of the manufacture of iron and steel. It was not permissible to criticise the address nor to raise any discussion upon it, and he would therefore content himself with merely moving the resolution, except that he should like to refer for a moment in passing to the paragraph in which the President had called attention to the American volume, in order that he might ask the members to join with him in acknowledging their great indebtedness to the gentlemen who had given so much time to the preparation of that volume and made such interesting reflections upon the visit of the Institute to America. He was not including himself because he had written a short preface to the volume, but in that preface he had ventured to say that the volume would be found to be of great interest, and that it would be a credit to the Institute. He happened to know from personal observation what an immense amount of time and labour Sir Lowthian Bell had given to the preparation of his account of their American proceedings. He had devoted months to the collection of the material which he had placed before the members, and to the preparation of all the particulars which he had set forth in his usual lucid style. It was due to Sir Lowthian Bell that attention should be called to that circumstance, and that thanks should be voted to him for the services which he had rendered. Mr. Snelus also, who had taken charge of the Canadian section, and had given a full account of the proceedings of the representatives in Canada, was entitled to their warmest thanks. The President in his address had spoken somewhat

hopefully on the condition and the prospects of the manufacture of iron. It was certainly to him (Sir J. Kitson) a matter of satisfaction to remember that fifteen years ago, at the meeting in Paris, he had ventured to make some observations on that subject, and had stated that they had some years before them to prepare for the inevitable destruction of their trade by jubilant members of the steel trade.

He was now glad to congratulate the President in being in the chair not as a steel manufacturer but as an iron manufacturer, representing that section of the Institute which he believed had a good many kicks in it yet before it went out of existence. The President had concluded his address with a rather doleful expression—that nothing was left for the iron and steel trade but hope. It was true that hope would not resuscitate the dividends of those shareholders whom the President seemed to be so much afraid of meeting; but he believed that there was something more than hope before them. Although things were very gloomy, he could see some signs of improvement. They knew perfectly well that the iron and steel trade of England could only recover when based on very low prices of raw material. They had now steel rails being shipped at 75s. per ton or perhaps less, but they did not like to talk of lower prices. They had heard of steel ship plates being produced at £5 a ton or under, and the results were already apparent in the shipbuilding trade. They knew that during the last few months more orders had been placed than ever during the twelve months past, owing to the extraordinarily low prices at which ships could be produced. He had heard during the last month or so that cargo steamers with triple expansion engines could be put upon the market at £6, 10s. per ton measurement, a state of things which their ancestors would have deemed impossible, and a state of things which made it certain that England would remain, as it now was, the first shipbuilding producing country in the world. More ships were being put into the market because there was more trade in the world. Freights were increasing, and he ventured to think that there was something beyond hope to encourage the President in his efforts to keep the Institute vigorous, and to encourage the members to do their utmost to maintain the supremacy of the great industries with which they

were connected. It was a happy augury that they had a practical man like Mr. Windsor Richards occupying the chair, and he desired to congratulate him and the Institute on the admirable address which he had delivered.

Mr. HOWARD KENNARD said he rose with great pleasure to second the resolution. The President had delivered one of the most eloquent addresses that had ever been heard in the Institute. There was no man more eminent in the iron trade than their new President. He had first of all been thoroughly educated in South Wales, and then took charge of the largest works in the country, and finally he had retired to the Upper House of the trade, and taken the management of the works that produced the very finest iron not only in this country but in the world. He quite agreed with the President that there was still hope left for the trade, and he also concurred in the remarks he had made as to the shameful way in which the railway system in India was allowed to languish. Notwithstanding the railways there were producing good interest for their money, and there was any amount of money in England ready to be invested in them, there was still a great deal of apathy in the Government, which allowed the country to be practically ruined for want of communication. It was that sort of thing that occasioned depression in the trade. If instead of making the present number of railways in India the Government made ten times the number, they would have some work to give to their men, and should not be deploring the dreadful condition in which the trade was placed. In conclusion, he could only say that they were all proud that the country could produce such men as Mr. Windsor Richards, in whose hands they felt confident that the great industry which they represented would be well cared for.

The vote of thanks to the President was then unanimously agreed to.

The PRESIDENT said he desired to thank the members for the hearty manner in which they had responded to the resolution.

The Bessemer Gold Medal.

The PRESIDENT said it would be observed that the Bessemer medal had been awarded to Mr. JOHN FRITZ, of Bethlehem, Pennsylvania. On May 7 the Council cabled to Mr. Fritz notifying him of the award of the Bessemer medal, and inviting him to the meeting. Mr. Fritz replied that he appreciated the honour conferred most highly, and offered his sincere thanks to the Council. Since then the Council had received the following letter:—

SOUTH BETHLEHEM, PA., *May* 7, 1893.

E. WINDSOR RICHARDS,
President, The Iron and Steel Institute,
Victoria Mansions, London.

SIR,—I have the honour to acknowledge the receipt of the following telegrams from the General Secretary and yourself:

"LONDON, *April* 28, 1893.

"JOHN FRITZ,
Bethlehem, Pa.

"Council Steel Institute award you Bessemer medal. Your attendance invited May 24th. JEANS."

"LONDON, *April* 28, 1893.

"FRITZ,
Bethlehem, Pa.

"As President I will present your medal. Please come.
"WINDSOR RICHARDS."

and to confirm my telegraphic reply:—

"BETHLEHEM, PA., *April* 28, 1893.

"RICHARDS AND JEANS,
Steel Institute, Victoria Mansions, London.

"Appreciate honour conferred most highly. Present sincere thanks to Council. Will write. FRITZ.

Please accept and convey to the Council my thanks and grateful acceptance.

I not only appreciate most highly the honour which its award confers, but shall further esteem it as an ever present mark of the friendship and remembrance of my friends and co-workers in the vast field of iron and steel industries of which the Iron and Steel Institute of Great Britain has been so able an exponent.

I regret that my professional obligations will prevent my accepting your invitation to be in London, May 24th, to personally receive the medal which bears Sir Henry Bessemer's eminent name, as it would give me an opportunity to more fitly show my appreciation of the honour the Institute has conferred upon me, and to again greet in person the many warm friends whose friendship I prize.

Please convey to all my gratitude and remembrance, and allow me to remain, yours respectfully, J. FRITZ.

It was somewhat unfortunate that Mr. Fritz was not present to receive the medal, but Sir Lowthian Bell had kindly promised to receive it for him. Having known Mr. Fritz for many years, and having for him personally such a high regard and respect, it was a very great pleasure to him, as President of the Iron and Steel Institute, to present the Bessemer gold medal unanimously offered for his acceptance. Mr. Fritz began his career as a humble artisan, and by his indomitable perseverance and singleness of purpose he had attained the highest position in his country as a metallurgist, an engineer, and a manufacturer. In 1846 he had charge of the Norriston Ironworks; in 1850 he was mechanical engineer at Safe Harbour; in 1854, as chief engineer and general superintendent, he rebuilt the Cambria Works; and in 1857, in conjunction with his brother, George Fritz, he designed and erected the well-known three-high blooming-mill with automatic feed-tables, also the three-high rolling-mill. In 1860 he designed the entire plant of the blast-furnaces, forge, and mills at Bethlehem, in the capacity of chief engineer and general superintendent. In 1868, in conjunction with Alexander Holley and George Fritz, he erected the Bessemer plant at Bethlehem, which for a period of twenty years held the first place in America for the quality and quantity of its product. He was one of the small band of leaders who so successfully developed the Bessemer process in the United States, and astonished the metallurgical world by the enormous quantities of steel produced from comparatively small installations. During the last few years he, in connection with Lieutenant Jacques, designed, constructed, and managed one of the most important armour-plate, plant, and gun-making works in the world, producing the highest quality of open-hearth steel. The magnitude of this undertaking must be seen to be at all appreciated. On behalf of the Iron and Steel Institute he

presented the Bessemer gold medal to John Fritz, it being the highest honour in their power to confer on him.

Sir LOWTHIAN BELL, Bart., F.R.S., in receiving the medal, said it was always a subject of very great pleasure to himself to take a part, however humble, in endeavouring to extend the friendly relations which had been cultivated for twenty years or more between the iron-makers of this country and those of the United States. He had a similar pleasant duty to perform many years ago in receiving the gold medal from the hands of the then President in order to transmit it to his late friend and eminent citizen of the United States, Peter Cooper. It was with the utmost satisfaction that he had this second opportunity of accepting on behalf of his old friend, John Fritz, the very handsome testimonial of their approbation and commendation of the great services which he had rendered to the science and the manufacture of iron and steel. Though they would all regret the absence of Mr. Fritz, knowing as they did his very modest character, it was certain that if he had been present he would have very greatly depreciated his own merits. In that respect perhaps they were rather gainers than losers by his absence.

The PRESIDENT said that for the first time the medal had been presented in the absence of Sir Henry Bessemer, who, however, had written to express the hope that his state of health would enable him to be present some time during the meeting.

The following papers were then read :—

ON THE ELIMINATION OF SULPHUR FROM IRON.

By J. E. STEAD, Middlesbrough.

PART II.

Sulphur in the Puddling Process.

Since the first part of this paper was read special experiments have been made to ascertain the exact nature of the change which occurs when fluid oxides of iron act upon fluid iron containing sulphur.

The imperfect trial previously described tended to show that provided the cinder is not charged with any large quantity of ferric oxide, no gas having a smell of sulphurous acid is given off; but as this was not conclusive, a more careful and elaborate experiment was conducted, which I think is more satisfactory.

One clay crucible was luted into the upper part of another, so as to produce an air-tight joint.

Into the uppermost crucible was securely fixed a long porcelain tube: the whole arrangement in reality constituting a clay retort, with a porcelain tubulure.

Before the crucibles were cemented together a mixture of coarsely-powdered sulphurous white iron and basic ferrous silicate was placed in the lower one.

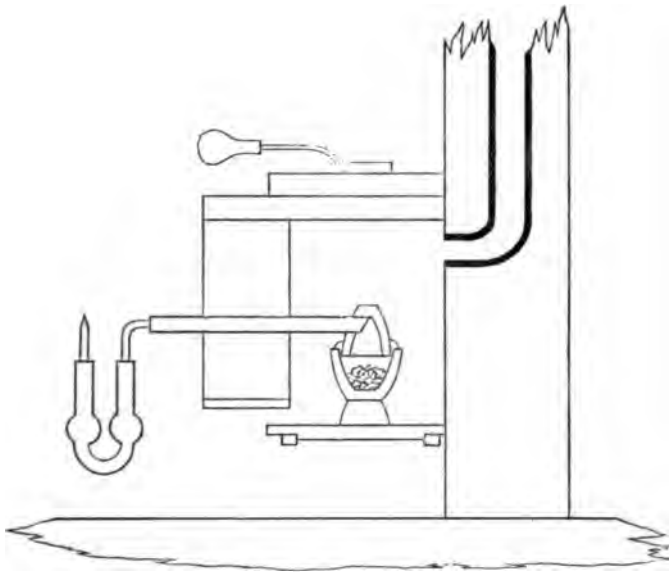
The retort with its contents was then placed into a coke furnace, and was so fixed that the porcelain tube projected through the brickwork quite clear of the fire.

To the end of this tube a U tube containing a caustic alkali solution was attached, and when all was thus prepared the furnace was lit. The accompanying sketch (page 49) will make the arrangement clearly understood.

As soon as the melting-point of the iron was attained a brisk

olution of gas commenced, which burnt on applying a light with lear blue flame.

The whole of the gas was passed through the caustic liquor, so at every trace of sulphurous acid which might be given off would absorbed by it. When the gas ceased to be evolved the furnace s allowed to cool, and the spongy mass of cinder and iron crushed,



l a sufficient quantity of each was separated for analysis, and e caustic liquor, after acidulation and oxidation with bromine ter, was examined for sulphuric acid.

The following are the analyses of the several samples, viz.:—

	Cinder.	
	Before. Per Cent.	After. Per Cent.
Ferrous oxide	66·87	56·25
Ferric oxide	13·14	1·43
Iron combined with sulphur	0·28	3·95
Silica	16·70	25·25
Sulphur	0·16	2·26
Manganous oxide	0·86	1·86
Phosphoric acid	0·11	4·84
Not determined	1·88	4·16
	100·00	100·00

	Metal.	
	Before. Per Cent.	After. Per Cent.
Carbon	1·85	traces
Manganese	0·09	0·05
Silicon	0·05	none
Sulphur	1·83	0·596
Phosphorus	2·10	0·901

The proportion of metal and cinder used was 200 grammes and 100 grammes; but it was impossible to determine the proportions remaining after the treatment, as they were so intimately mixed that they could not be separated.

The amount of sulphur absorbed by the caustic alkali was equal to 0·0024 per cent. of the metal treated, or practically only a trace.

It would appear from this that no sulphurous acid is formed directly by the oxidising action of ferrous oxide on the sulphur in fluid iron, but that sulphur existing as sulphide in the iron is found in that state in the cinder.

The next question to answer is whether the sulphur is absorbed directly as such, or whether sulphide of iron is dissolved out of the metal by the oxides of iron.

The Action of Free Sulphur on Basic Ferrous Silicate.

An experiment was made in which sulphur vapour was passed through ferrous silicate with the following results:—

		Cinder.	
	Original Cinder. Per Cent.	After Treatment with Sulphur. Per Cent.	After Further Action. Per Cent.
Sulphur	0·21	1·96	2·87

It would appear from this that basic silicate of iron is capable of absorbing free sulphur; but whether it has the power to withdraw sulphur from sulphide of iron in fluid metal (taking the sulphur and leaving the iron) is a question which requires further investigation.

The most probable reaction, to my mind, is that, as basic silicates freely dissolve sulphide of iron, that substance is bodily dissolved

out of the iron, and that in the puddling process the sulphur is afterwards partially converted into SO_2 by oxidation, and escapes in that state.

The Relations of Iron, Calcium, Sulphur, and Oxygen, when together in Fusion.

Several of my deductions and experiments have been somewhat severely criticised by Mr. Hilgenstock of Hoerde, and it is impossible for me to act otherwise than to give the most careful consideration to the remarks of so eminent an authority.

The original article appeared in *Stahl und Eisen*, January 15, 1893.

In this article he says, "We cannot recognise in calcium chloride and lime a suitable material for the removal of sulphide of iron from liquid iron to obtain the sulphur in the state of sulphide of calcium in the slag."

"We maintain that a third strong reducing agent is necessary in order to convert the sulphide of iron by the agency of lime into sulphide of calcium."

He further controverts the deductions drawn by myself on subjecting the compound formed by heating together sulphide of iron and lime to a red heat in a stream of hydrogen gas, in which it will be remembered that, having obtained a loss of oxygen corresponding to that which by calculation would be given off if the iron existed as oxide, I considered, therefore, that the compound was really $CaS+Fe_nO_n$ and not $FeS+CaO$, for neither sulphide of iron nor sulphide of calcium are affected by hydrogen gas.

In proof of my error he practically repeated my experiment, and found precisely the same result; but formed an entirely different theory, namely, that when FeS and CaO are in intimate contact, they exist as such till the reducing action of hydrogen is brought into play, and that the reaction really is: $FeS+CaO+H=CaS+Fe+H_2O$, and not $FeS+CaO=FeO+CaS$.

In further proof of the theory that the compound is really a mixture of FeS and CaO, and to settle the question, he took advantage of the fact that liquid iron readily absorbs sulphide of iron, but has no effect on sulphide of calcium, and conducted an experiment

at Hoerde, in which "on the bottom of a glowing basic crucible a mixture of one part of sulphide of iron ground fine and one part of lime was placed, and liquid iron was poured on it immediately."

The iron before and after had the following composition, viz.:—

	Before. Per Cent.	After. Per Cent.
Sulphur	0·077	0·270
Carbon	0·840	0·710

"As the powder was only about 5 per cent. of the bulk of the iron, the fact of its absorbing sulphide of iron in spite of the presence of carbon shows its great affinity."

"Here appears the error in the foundation of Saniter's process."

He further states that none of the experiments prove that it is the action of the mixture of lime and calcium chloride which caused the elimination of sulphur, shown by Saniter and myself to take place, and suggests that it may be attributed to some other causes.

He opposes also what he calls a well-known error, that lime is a universal remedy against sulphur, and maintains that "although it is of valuable service in the blast furnace, it is of little use for desulphurising in the converter and reverberatory furnace, on the ground that the relation of lime to sulphide of iron corresponds to that of protoxide of iron, manganese, and others—they dissolve sulphide of iron;—but that in spite of this power these oxides are not desulphurising agents, and that if we admit that they did, when in basic slag, remove sulphide of iron from liquid iron, there will still remain the lime basic unfavourable slag."

He then describes an experiment in which sulphate of lime was strewn upon the surface of molten iron, contained in a basic-lined vessel, and in which it was shown the iron absorbed 0·416 per cent. of sulphur from the lime sulphate, which experiment practically confirmed that of Finkener.

Based on these experiments, Hilgenstock formulates the following law:—

"*The incomplete desulphurisation in lime basic refining is caused by the regular production of calcium sulphate and its decomposition by the iron bath which re-absorbs the sulphur.*"

He then points out that sulphate of lime at a white heat, when in the solid free state and not dissolved in slag, is completely decomposed, free lime with no trace of sulphur in it remaining, whereas if it is dissolved in calcium chloride and similarly treated only half of the sulphur is expelled, and from this result assumes that lime basic slags dissolve the sulphate of lime, which he also assumes is produced continuously in the converter, and that it is, on coming into contact with the fluid iron, instantly converted into free lime, oxide, and sulphide of iron, the latter substance being absorbed by the bath, and he makes himself very clear by stating "that all or nearly all the sulphur which troubles us in making ingot iron has once in passing existed as sulphurous acid which would pass away harmless in the form of gas were it not retained and converted into sulphate of lime by the lime in the basic slag, the iron taking the sulphur back again from the sulphate of lime so formed."

He then shows by two experiments, that when air containing dry sulphurous anhydride is passed over a mixture of equal parts of lime and oxide of iron in one experiment, and over a cinder containing 70 per cent. oxide of iron, 20 per cent. oxide of manganese, and 10 per cent. of silica in the second, both mixtures being maintained at a white heat for fifteen minutes to the action of the sulphurous gas, the lime basic slag absorbed 7·025 per cent. sulphuric anhydride, but the metallic basic slags absorbed none.

Briefly Mr. Hilgenstock's position is as follows:—

1st. He considers as proved that lime and sulphide of iron at high temperatures remain as such, and that liquid iron is capable of dissolving and does dissolve out the sulphide of iron from basic lime slags.

2nd. He assumes (for no proof is given) that sulphuric acid is produced in the basic converter in presence of lime by the action of oxidising agents on the sulphur in fluid iron.

3rd. It is assumed that sulphur is oxidised directly to sulphurous anhydride in the puddling and other processes, depending on the action of metallic oxides $Fe_nO_n + MnO$, which, as soon as it is formed, passes away as gas, for he has proved that metal oxide slags cannot absorb it, and that the difference in the metal basic

and lime basic processes is practically this, that in one the slag absorbs the sulphurous gas, and in the other it does not; but it is evidently assumed that sulphurous anhydride is continuously produced in both.

It must be admitted by all that the theories advanced indicate considerable ability and knowledge, and it must also be admitted that the theory that the loss of the oxygen of the compound $Fe(CaO_2)S$, when heated in hydrogen, is not absolute proof that the compound consists of $FeO+CaS+CaO$. On the other hand, Herr Hilgenstock perhaps forgets that in his experiment he did not first frit together his mixture in a closed vessel, but heated the mechanically mixed powders directly in the porcelain tube, and overlooks the possibility of the change $FeS+CaO=FeO+CaS$ taking place in the tube although in the presence of hydrogen, yet unassisted by it, and that the compound might not have been affected by the hydrogen till such change had taken place.

His experiment may therefore be said to have been practically the same as mine, but that it is no positive proof that oxide of iron and sulphide of calcium is not the natural condition in which iron, calcium, sulphur, and oxygen associate or arrange themselves when heated together; it is therefore necessary to look in other directions for the proofs which this experiment fails to give.

The statement giving the result of sprinkling sulphate of lime on fluid iron in which the sulphur was absorbed by the iron, on the face of it, seems to assist Mr. Hilgenstock's position; but as we have not been furnished with an analysis of the fluid iron, it is impossible to consider it, knowing as we do that if much silicon was present it would be oxidised, and cause a precipitation of sulphide of iron according to the following approximate reaction—

$$(CaSO_4)_n+(Fe)_n+(Si)_n=(CaSiO_3)_n+(FeSiO_3)_n+(FeS)_n.$$

And as there was no excess of free lime, it does not show or disprove what I have contended, that when free lime in excess is associated with sulphur and iron, in presence of liquid iron or steel, the sulphur is not absorbed by the iron, but is retained in the cinder.

The experiment in which molten steel was poured upon the mixture of equal parts of lime and sulphide of iron containing about 50 per cent. excess of lime above what would be required to combine with the sulphur appears at first consideration conclusively to demonstrate the soundness of Mr. Hilgenstock's position. As, however, the results were so different from those I had previously obtained, and which have already been placed on record, I took the advice of my friend, and repeated his own experiments in various modifications.

For this purpose a mixture of sulphide of iron and lime in equal proportions was powdered and mixed and was heated in a closed crucible till it sintered into a frit.

This had the following approximate composition, viz. :—

	Per Cent.
Iron	35·74
Sulphur	14·13
Calcium	35·00
Oxygen, &c.	15·13
	100·00

The first experiments were made with two classes of iron, in which two parts of the metals were melted with one part of the mixture in lime-lined crucibles.

The crucibles were securely covered with basic material in each case.

The results were as follows :—

Description.	Pure Carbon Iron.		Cleveland Pig.	
	Before.	After.	Before.	After.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	3·95	2·90	3·350	3·300
Manganese . . .	0·36	0·10	0·750	0·450
Silicon	0·03	0·01	3·320	1·160
Sulphur . . .	0·008	0·016	0·030	0·027
Phosphorus . . .	...	...	1·560	1·160

Here we see that although the crucibles were most tightly closed, there has evidently been at work some energetic oxidising

agent, and as the only substance present capable of giving oxygen was the cinder, we are safe in assuming that it most probably was responsible for the oxidation.

This oxidation tends to show either that the mixture consisted of sulphide of calcium and oxide of iron, or as sulphide of iron and lime in an unstable condition, ready to be converted into the calcium sulphide and oxide of iron under the slightest impulse from reducing agents present, carbon and manganese, or that the sulphide of iron is prevented by the excess of lime from returning to the metallic bath in the same way that oxide of iron behaves in the puddling process.

The non-absorption of sulphide of iron from the great mass of the mixture does not support the second hypothesis.

In the next experiment pure carbon metal was melted in one case upon a bed of sulphate of lime after covering with a layer of the same material, and in another the mixture used for the bed and covering consisted of 80 per cent. sulphate and 20 per cent. lime.

The following results were obtained:—

	With $CaSO_4$ alone.		With 4/5 $CaSO_4$ and 1/5 CaO.	
	Before. Per Cent.	After. Per Cent.	Before. Per Cent.	After. Per Cent.
Carbon .	3·950	1·40	3·95	2·3
Sulphur .	0·008	0·075	0·008	0·008

The fusions were made in lime-lined crucibles.

Here the results tend to show that sulphate of lime, when not associated with free lime, does give a portion of its sulphur to liquid iron, but that an excess of free base prevents it.

In the experiment with Cleveland iron a notable amount of phosphorus was removed. In order to ascertain what the effect of $Fe(CaO)_2S$ is upon phosphide of iron containing no other elements than phosphorus and iron, they were melted together in a lime-lined crucible and the resulting metal and slag were carefully examined, with the following result:—

	Phosphide of Iron.	
	Before. Per Cent.	After. Per Cent.
Iron	88·80	91·20
Phosphorus	10·80	8·60
Not determined	0·40	0·20
	100·00	100·00
Slag contained phosphoric acid	0·11	2·39

Probably more phosphorus would have been removed had the cinder been more fluid.

In the next trials molten steel from an open-hearth furnace was poured—

1st. Upon a quantity of the powdered fritted mixture which had been previously heated to redness in a lime-lined crucible.

2nd. Upon the mixture which had been diluted with 20 per cent. of fluorspar to increase its fluidity.

3rd. Upon red-hot sulphate of lime.

The crucibles and contents could not be maintained at a sufficiently high temperature to admit of the action between the steel and the various substances being continued for more than ten or twenty seconds, as the steel rapidly became solid.

The lower portion of the steel which had melted its way into the material at the bottom of the crucible was therefore in each case taken for analysis.

The following were the results obtained :—

Description.	Steel Used.	After pouring on $Fe(CaO)_2S$.	After pouring on $CaSO_4$.
	Per Cent.	Per Cent.	Per Cent.
Carbon	0·370	0·380	0·400
Manganese	1·268	0·950	0·576
Sulphur	0·066	0·066	0·101

The sulphate of lime appeared to be most energetically acted upon by the steel, and a black cinder floated to the surface.

This cinder contained iron, calcium, sulphur, and oxygen, but not a trace of sulphate of lime.

An experiment in which fluorspar was used in conjunction with $Fe(CaO)_2S$ was made on a "casting charge" of steel; the crucible was raised to a bright red heat; the contents were in a pasty

condition before the steel was poured, and the experiment was conducted on a larger scale than in previous trials.

The following results were obtained:—

Description.	Before.	After.
	Per Cent.	Per Cent.
Carbon	0·380	0·400
Manganese	0·403	0·186
Silicon	0·112	0·028
Sulphur	0·184	0·121

In all these trials with $Fe(CaO)_2S$ there is direct evidence of the presence of an oxidising agent, but in none any evidence of the presence of free sulphide of iron.

The latter experiments were not so satisfactory as could be wished, but they are quite sufficient to prove that the material in the crucibles had acted upon the steel, for both the manganese and silicon are shown to have been removed.

We have now apparently most conflicting evidence. Mr. Hilgenstock's own experiments in my hands give exactly opposite results to those obtained by him.

In carefully reading the description of how the trial was made at Hoerde, and comparing it with my own, we notice this slight difference. At Hoerde the mixture of sulphide of iron and lime was not previously fritted by heating (which it was in my trials), but was placed as a mechanical mixture into the crucible the moment before the steel was poured on the top of it.

Now it appears to me that in this experiment the sulphide of iron and lime must have been in a separate state at the time the steel was poured upon them, consequently the sulphide of iron being free would be partially absorbed by the steel and partly by the lime.

In other words, there were two bodies at the moment the steel and mixture were brought together ready to absorb sulphide of iron, and according to the results the lime, as we should naturally expect, got the most, for of the 0·70 per cent. of sulphur in the 5 per cent. of mixture used, the lime retained 0·507 per cent., and the steel 0·193 per cent.

Had the mixture previous to pouring the steel upon it been

fritted so as to allow the lime to secure the sulphide or sulphur, I anticipate a very different result would have been obtained.

Mr. Hilgenstock's statement that liquid iron is capable of dissolving out sulphur from the lime basic slags is not only negatived by all my experiments, but is constantly shown to be incorrect in the basic Bessemer converter whenever sulphurous iron is converted into steel, for, as will be shown presently, such lime basic slags become charged with sulphur during the after-blow, and yet no matter how long they are kept in contact with the metal afterwards, there is no re-absorption of sulphur.

We must now pass on to consider the question as to whether sulphate of lime is likely to be formed in the basic converter.

The most direct way to answer this question is to examine basic slags for sulphate of lime.

Hilgenstock himself has published several analyses, but invariably all the sulphur has been returned as sulphide of calcium, and in no case have I ever met with such slags containing any sulphates.

It is impossible to understand how, in the Bessemer converter, sulphates can be formed according to Hilgenstock's hypothesis, for, in the first place, sulphurous acid in direct contact with the metal must be formed, and this must then combine with a further quantity of oxygen on coming into contact with the lime slag to convert it into sulphate of lime, but from all experiments, both of Finkener and others, such a compound is instantly destroyed in coming into contact with hot iron.

How then, I ask, is it possible for sulphate of lime ever to be formed in presence of an overwhelmingly large proportion of fluid metal?

It does not seem at all probable.

In the Bessemer process, judging from practical trials made many years ago, which are recorded in the Proceedings of the Institute of Cleveland Engineers, it was shown that at or near the point at which the air entered the metal, practically the iron, phosphorus, silicon, and manganese were burnt in the ratio in which they existed in the metal, and that the very basic iron slag, in passing upwards through the metal, acted upon the more readily oxidisable bodies, the iron returning again to the metallic state,

whilst the silicates rose to the surface or the carbon oxides passed off as gas.

Now, taking into consideration the knowledge we now have, there can be little doubt that the oxide of iron at first produced near the tuyeres does dissolve a portion of the sulphur from the bath, and possibly the higher oxides of iron may react on this sulphide and form sulphurous acid; but judging from the fact that there is practically no loss of sulphur in the early stages of the blow, we may safely assume that it is reduced again by the iron, and never allowed to reach the lime slag.

It seems to be forgotten that the basic Bessemer process is very similar to the acid process, and that practically in neither is any sulphur removed up to the time when the carbon is burnt out.

In one process there is no basic lime slag, and in the other it is present.

If sulphurous acid was formed, and reached the siliceous slag incapable of retaining it, it would most surely escape as sulphurous acid, and the metal would contain less sulphur; but it does not contain less, and as the changes in the acid and basic Bessemer processes are practically the same during the first stages, I cannot see how sulphurous acid can ever reach the lime slag, or how sulphate of lime can be formed.

From what I have shown it is clear that metallic oxides in the puddling process do not oxidise sulphur to SO_2 directly, but that SO_2 is without doubt formed at a secondary stage by the action of the higher oxides of iron (always present) upon the sulphide in the cinder.

It has been practically proved that sulphate of lime in the lime added to the charge in the converter causes an increase of sulphur in the metal, but I have not been able to obtain any account showing what proportion of it is so absorbed.

I can understand how a portion of it during the early stages of the blow would get into the metal, for the silica formed very rapidly produces a siliceous slag with the lime, and this might cause a precipitation of sulphide of iron.

This leads at once to the consideration of the behaviour of sulphur in the basic Bessemer process.

Sulphur in the Basic Bessemer Process.

Most carefully taken samples have been placed at my disposal by Mr. Jos. Walton, who obtained them from the Glengarnock Steel Works.

These samples were taken at various periods during the progress of the blow in the Bessemer converter.

They were all examined in my laboratory, with the following results:—

Analyses of Metal.

Description.	Metal.	1st Period. Desiliconised.	2nd Period. Decarburised.	3rd Period. Dephosphorised.	4th Period. Steel.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent
Carbon . . .	2·32	2·180	0·07	0·02	...
Manganese .	0·66	0·200	0·09	0·06	...
Silicon . . .	1·57	0·300	0·07	trace	...
Sulphur . .	0·16	0·148	0·16	0·08	0·070
Phosphorus .	1·85	1·920	1·53	0·04	...

Corresponding Cinder.

Description.	1st Period. Desiliconised.	2nd Period. Decarburised.	3rd Period. Dephosphorised.	4th Period. Steel.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Lime	44·30	47·00	46·70	...
Magnesia . . .	0·72	0·86	1·80	...
Manganous oxide . .	6·60	4·46	2·51	10·79
Ferrous oxide . .	4·38	8·23	14·02	9·00
Ferric oxide . . .	1·29	1·00	4·29	2·14
Alumina . . .	0·35	0·26	0·30	...
Silica	39·20	29·80	14·90	...
Phosphoric anhydride .	2·61	7·83	14·86	...
Sulphur . . .	0·16	0·10	0·36	0·36
Phosphorus . . .	1·14	3·41	6·49	...
Probable per cent. of liquid slag on 100 per cent. of metal	Per Cent. 7	Per Cent. 11	Per Cent. 27·00	

Sulphur in lime used = 0·054 per cent.

Assuming that the weight of slag per cent. of metal used was

as given, we have the following sulphur account up to the end of the after-blow:—

Sulphur in Cinder.	Sulphur. Per Cent.
27 per cent. of cinder at 0·36 per cent. sulphur . . .	0·097
Less sulphur added in the lime, 15·2 per cent., at 0·054 per cent. sulphur	0·008
Total received from metal	0·089

Sulphur removed from Metal.	Sulphur. Per Cent.
100 parts of raw iron contained	0·160
Less 85 parts of blown metal at 0·080 per cent. sulphur .	0·068
Total removed	0·092

The sulphur removed during the fore-blow calculated from the analyses of the cinders is as follows:—

After 1st Period.

The sulphur in 7 per cent. slag at 0·16 per cent. sulphur, less 0·025 carried in by the lime, is equal to } 0·009 on 100 of metal.

After 2nd Period.

The sulphur in 11 per cent. slag at 0·10 per cent. sulphur, less 0·026 carried in by the lime, is equal to } 0·008 on 100 of metal.

Mr. C. H. Ridsdale, of the North-Eastern Steel Works, has kindly provided me with the results of his experience, which are as follows:—

Description.	Sulphur	In Slag.
	Per Cent.	Per Cent.
1. Metal poured into vessel	0·100	...
2. After blowing five minutes	0·118	...
3. At the drop of flame	0·118	...
4. At first sampling	0·074	0·377
5. At finish of blow before adding ferromanganese	0·071	0·391
6. Steel taken fifteen minutes after No. 5 .	0·057	0·480

Both series of experiments confirm each other, and also confirm the statement of Dr. Wedding that it is only during the after-blow that any more than traces of sulphur is eliminated, but they do not indicate any material volatilisation of sulphur, for all is accounted for in the slag.

An attempt must now be made to determine how it passes out of the metal and eventually finds its way into the slag.

First, there is the statement of Wedding that "many special investigations have proved that during dephosphorisation manganese returns to the metal bath, where it effects an elimination of sulphur."

In proof of such behaviour the following analyses of samples from the bath, taken March 16, 1887, may serve:—

Heat.	Description.	Mn.	P.	S.
		Per Cent.	Per Cent.	Per Cent.
No. 184	Upon disappearance of spectrum line	0·19	2·070	0·133
	At second lime addition . . .	0·62	0·463	0·067
	Upon addition of FeMn., steel test	Undetermined	0·110	0·052
No. 185.	Upon disappearance of spectrum line	0·24	2·180	0·072
	At second lime addition . . .	0·81	0·718	0·042
	Steel test	Undetermined	0·075	0·026
No. 186.	Upon disappearance of spectrum line	0·24	2·390	0·081
	At second lime addition . . .	0·79	0·483	0·047
	Steel test	Undetermined	0·082	0·056

These results are most remarkable, and, if I understand them aright, it would appear that after the manganese, silicon, and carbon are removed on the addition of lime, manganese returns to the bath.

If this is correct, it means, either that the phosphorus in the iron has power to reduce MnO liberated by the lime, or that the iron at elevated temperatures and in preponderating mass has a greater attraction for oxygen than manganese.

In order to test whether phosphorus combined in iron is capable of reducing oxide of manganese when they are melted together, one hundred parts of phosphide of iron was mixed with twenty parts of oxide of manganese, both in fine powder, and the mixture was melted in a lime-lined crucible with the following results:—

	Phosphide.	
	Before. Per Cent.	After. Per Cent.
Iron	87·50	86·20
Phosphorus	12·38	10·10
Manganese	0·12	3·24

	Oxide.	
	Before. Per Cent.	After. Per Cent.
Phosphoric acid	0·05	11·2

It is clear from these results, that under certain conditions phosphorus is capable of reducing, and does reduce, oxide of manganese. It probably does so in the basic converter when an excess of lime is present in the slag. It is a little more difficult to prove that the manganese so reduced effects an elimination of sulphur. It would appear that whether the manganese is present in large or small quantity in the slag, desulphurisation is effected about equally in each case.

Dr. Wedding may, however, have in his possession the practical proofs which I have failed to obtain, and if that is so, we should all welcome a communication from him to this Institute giving us the benefit of his knowledge.

After the experiment previously described, which clearly demonstrated that fluid oxides of iron remove sulphur from iron without the formation of sulphurous anhydride, the changes during the after-blow appear to be simple enough, for it is necessary only to remember that the conditions at the final stage of the Bessemer process approximate almost exactly to those which exist in the first stage of the puddling process. It must be remembered, too, that the oxide of iron present in excess in both processes most probably behaves in the same way in each, dissolving out from the metal the sulphide, which, in passing upwards through the metal in the basic Bessemer process, is finally received by the calcareous slag, where, I contend, it is converted into sulphide of calcium and oxide of iron, but where, according to Hilgenstock, it must remain as sulphide of iron.

The fact that, when the sulphur has been received into the basic slag, there is no tendency for it to return to the bath, which it never does, is most conclusive proof that either no sulphide of

iron is present, or that, if it is present, the lime basic slag has a greater attraction for it than the liquid iron.

Mr. A. Pourcel, in a paper* on the "Application of Thermal Chemistry to Metallurgical Reactions," makes the following statement, which has reference to the behaviour of sulphur in the acid and basic converter.

"Sulphurous anhydride gas cannot be formed in a medium where the temperature almost attains that of its total dissociation. The sulphur is concentrated in the acid converter. If the sulphur is eliminated by a prolonged after-blow in the basic Bessemer process, this is effected by the decomposition of the FeS by fluid CaO. We then have:—

$$\underset{\sim}{FeS} + \underset{\sim}{CaO} = \underset{\sim}{CaS} + \underset{\sim}{FeO}$$

$$\underbrace{-12 \quad -66}_{-78} \qquad \underbrace{-46 \quad +34}_{+80}$$

"The coefficient of affinity of this reaction is equal to $80-78=2$ calories, or in other words, it is very slight."

I now pass on to consider how it is that practically no sulphur is eliminated during the first stages of the blow by the calcareous slag.

In my opinion there are two reasons:—

1st. Because the lime, although present in sufficient quantity, is solid, and is only fluxed by the silicates which rise to the surface, and never become really very basic till near the end of the blow.

2nd. Because the mass of actual fluid cinder is very small compared with metal.

In the analysis of the basic process it will be noticed that at the end of the desiliconising period only 7 per cent. of scoria had formed, which had no less than 41·8 per cent. of acids in its constitution.

At the termination of the decarbonisation period the scoria was only 11 per cent. on the weight of metal, and contained 37 per cent. of acids, whereas at the termination of the after-blow the scoria weighed 27 per cent., and contained under 30 per cent. of acid.

It is generally admitted that at the termination of the blow, after the addition of manganese, there is a further elimination of sulphur.

* *Journal of the Iron and Steel Institute*, 1889, No. I., p. 163.

In the results given herein such elimination amounted to 0·010 per cent. and 0·014 per cent.

This has generally been attributed wholly to the manganese, but it seems most probable that the calcareous slag itself may have had some effect in removing it.

I have not had an opportunity of investigating this point, but I hope before long to make the necessary trials.

Sulphur in the Acid Bessemer Process.

Three charges of metal, and the steel produced from them, have been examined, with the following results:—

	Sulphur.	
	Before. Per Cent.	After. Per Cent.
No. 1	0·057	0·057
No. 2	0·066	0·047
No. 3	0·044	0·055

The results here seem to be variable, and cannot well be explained without further trials.

The average of the three results is as follows:—

	Per Cent.
Sulphur before	0·054
Sulphur after	0·053

This is equivalent to about 10 per cent. elimination of sulphur from the original metal, 100 parts of which would give about 90 of steel.

Sulphur in the Acid and Basic Open-Hearth Processes.

No opportunity has been afforded for the more careful study of the behaviour of sulphur in these processes.

I must therefore reserve this for future investigation.

The Hilgenstock or Hoerde Process.

Since our last meeting metal mixers have been introduced into two works in this country, with, I have been informed, most satisfactory results. It is hoped that in the discussion detailed

information will be given of the working of this process by those who have had it under their control.

Saniter Process.

The following results were obtained since the last meeting in my presence at the works of the Wigan Iron and Coal Company.

Crude Metal Process.—On three separate occasions metal from the blast-furnace was purified.

The material used and the metal before and after treatment were carefully treated in my laboratory, with the following results:—

Description.	Mixtures Placed on the Ladle Bottom.				
	1.	2.	3.	4.	5.
Lime	...	200	...	...	114
Carbonate of lime	350	...	350	350	114
Chloride of calcium	180	180	180	180	71
Fluor-spar	...	...	...	...	71
Weight of metal treated	10 tons	10 tons	10 tons	7 tons 16 cwts.	9 tons

Number.	Crude Metal.			Refined Metal.		
	Silicon.	Sulphur.	Manganese.	Silicon.	Sulphur.	Manganese.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1.	0·148	0·671	0·173	0·055	0·355	0·145
2.	0·345	0·578	0·288	0·224	0·387	0·259
3.	0·521	0·145	1·296	0·373	0·050	1·181
4.	0·345	0·166	1·294	0·073	0·036	1·096
5.	2·290	0·118	...	2·170	0·038	...

Number.	Sulphur Removed.		Sulphur in Slag.
	Per Cent.	Per Cent.	Per Cent.
1.	0·316	47·0	5·67
2.	0·191	33·4	5·49
3.	0·095	65·0	3·57
4.	0·130	84·0	3·50
5.	0·080	67·8	1·88

Analyses of Slags.

Description.	No. 3.	No. 4.
	Per Cent.	Per Cent.
Chlorine	14·60	14·90
Calcium	8·20	8·40
Calcium	4·46	4·37
Sulphur	3·57	3·50
Lime	35·32	35·89
Magnesia	0·57	1·08
Ferrous oxide	1·00	0·39
Manganous oxide	4·18	2·52
Alumina	3·70	2·67
Silica	24·60	25·90
Phosphoric anhydride	0·07	0·07
	99·77	99·69
Iron	0·77	0·30
Manganese	3·22	2·00
Sulphur	3·57	3·50
Sulphur capable of being combined with the manganese and iron	2·21	1·34

In purifying phosphoric iron containing very little silicon, phosphorus is oxidised, and is removed and retained by the slag as phosphoric acid.

Thus in No. 1 trial the slag contained 3·21 per cent. of phosphoric anhydride, and the crude iron only 0·14 per cent. of silicon.

This confirms my own laboratory experiments, and goes far to prove that sulphide of iron is dissolved by the chloride of calcium and lime from the crude iron, and is converted into sulphide of calcium and oxide of iron, and that the oxide so formed then reacts on some of the phosphorus, producing phosphoric anhydride, which in presence of lime basic slag forms phosphate, the oxide at the same time being reduced to iron, which returns to the bath.

It must not, however, be forgotten that any moisture in the chloride of calcium or any carbonic acid associated with the lime will also produce oxide of iron, and that these will also act as oxidising agents.

The fact that the iron and manganese are not in nearly sufficient quantity in the slag from Nos. 3 and 4 to combine with the sulphur present is absolute demonstration that sulphide of calcium must be present.

The reactions in this process are exceedingly complex, and there

are changes which occur of which we know little or nothing. It is, however, my opinion that the sulphide of iron is dissolved out of the metal in the first instance by the free or loosely attached dissolved lime. Similarly, when sufficient manganese is present, possibly sulphide of manganese is also dissolved out. I do not, however, care at present, without more extended investigation, to hazard any opinion as to what the subsequent reactions may be.

With regard to the belief that a powerful reducing agent is required to be present to effect the removal of sulphur from iron as calcium sulphide, I can only say that, if reducing agents are required, in fluid raw iron itself you have all the reducing agents necessary, so that it is not necessary to look for any such agents outside of the iron carbon, silicon, phosphorus, and manganese naturally present in all raw iron.

Desulphurising in the Basic Open-Hearth Furnace.

Saniter Process.—The following results were obtained on January 17, 1893, in working a charge of sulphurous iron and scrap at the Wigan Works. The analyses were made in my laboratory.

The charge was made up of the following materials:—

	On 100 Parts. Per Cent.	Tons.	Cwts.	Qrs.
Basic iron	71·13	12	0	0
Bought scrap	5·93	1	0	0
Pit scrap	17·78	3	0	0
Hæmatite	4·45	0	15	0
Ferro-manganese	0·41	0	1	2
Ferro-silicon	0·30	0	1	0
	100·00	16	17	2

Yield of ingots . 15 tons, 17 cwts. = 94·4 per cent.

	Cwts.	Qrs.	Lbs.
Chloride of calcium per ton	0	2	0
Lime	1	1	0
Limestone	2	3	20
Puddle mine	2	0	0
Purple ore	1	1	0

Furnace was full at 9.30 P.M., and melted at 3.30 A.M.

Bath was quite clear at 4 o'clock.

Samples of the metal and scrap used, and of those taken from the bath, had the following composition :—

Description.	Pig Iron.	Scrap.	Mixture.	4.5.	5.15.	7.15.	9.15.	11.30.	12.30.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per. Cent.	Per Cent.
Carbon . .	2·560	0·150	2·030	0·410	0·380	0·180	0·150	0·120	0·180
Sulphur . .	0·400	0·050	0·310	0·294	0·247	0·175	0·160	0·099	0·052
Phosphorus .	3·260	0·070	2·460	1·380	0·170	0·120	0·080	0·060	0·070
Silicon . .	0·672	0·010	0·500	0·028	0·019	0·019	0·020	0·028	0·056
Manganese . .	0·374	0·560	0·420	0·210	0·06	0·10	0·120	...	0·670

The accompanying diagram (Plate VI.) will make the changes which occur plain.

On the Irregular Distribution of Sulphur in Iron and Steel.

On this point an analyst cannot but speak feelingly, for there can be little doubt that different results, obtained by different chemists, which have been most discordant, have been attributed in many cases to the inefficiency of the analyst, when in reality the true cause has been due to difference in the drillings taken from various parts of the piece of iron or steel.

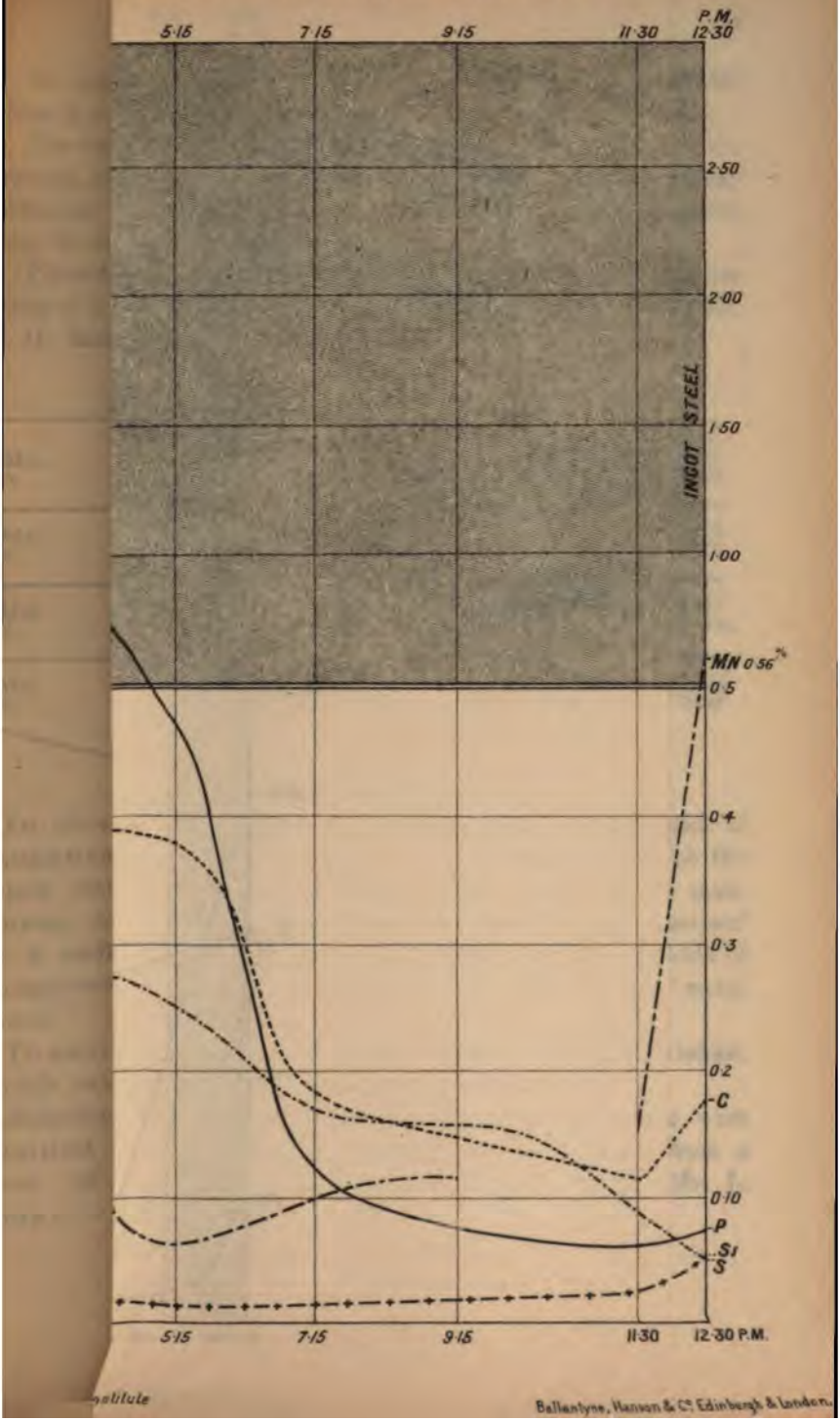
It is a well-known fact that just as in freezing ingots of peaty water the impurity is in great measure concentrated in the central axis of the mass, or, in other words, in that part which is last to become solid, so steel and iron, in passing to the solid state during crystallisation, tend to throw to the centre the impurities; consequently in certain central parts of the solid steel and iron there is frequently found a segregation consisting of material containing a very much larger proportion of carbon, sulphur, and phosphorus than the average of the whole mass.

It is fortunate that such less pure portions are not thrown to the exterior, but are concentrated in that part of the mass where they are least likely to have an injurious effect when the iron or steel containing such segregation is subjected to mechanical strains or stress.

It has been my experience that, as a rule, the larger the mass, and the more elevated the temperature at which steel is cast, the greater will the segregation be.

PLATE VI.

ANITER'S OPEN HEARTH PROCESS.



...stitute

Ballantyne, Hanson & Co. Edinburgh & London.

To obtain an average sample from such material in a suitable form is a rather difficult matter if the drill is used to procure it.

The only really reliable way is to plane a sectional face of the sample, and when this cannot be done, to take drillings from many different parts and mix them together, so that the whole section may be represented.

Variations in Basic Pig Iron.—The following analyses of different parts of a pig of basic iron have been kindly furnished to me by Mr. C. H. Ridsdale :—

Basic Pig.

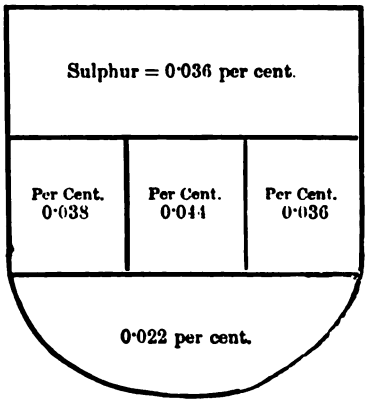
Per Cent.	Per Cent.	Per Cent.	Averages Per Cent.
Mn. . . . 2·400 S. 0·140	Mn. . . . 2·420 S. 0·105	Mn. . . . 2·420 S. 0·140	= 2·417 = 0·128
Mn. . . . 2·340 S. 0·068	Mn. . . . 2·400 S. 0·070	Mn. . . . 2·370 S. 0·079	= 2·370 = 0·072
Mn. . . . 2·190 S. 0·047	Mn. . . . 2·280 S. 0·044	Mn. . . . 2·100 S. 0·047	= 2·257 = 0·0493
Mn. . . . 2·220 S. 0·054	Mn. . . . 2·130 S. 0·040	Mn. . . . 2·100 S. 0·052	= 2·150 = 0·049

In this pig it will be seen that there is about 2·52 per cent. of manganese, and that the sulphur is in greatest quantity at the upper surface, where it had evidently been carried by the manganese, and there can be no doubt that had the pigs remained for a sufficient length of time in the fluid state the sulphide of manganese would have separated, just as it does in the "metal mixer."

To sample such material, complete sectional slices must be taken, which must be thoroughly disintegrated and mixed.

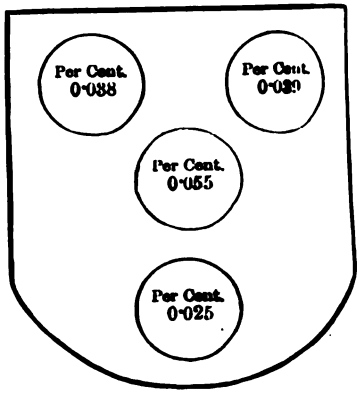
Sulphur in Hæmatite Pig Iron.—The following results were obtained in my laboratory on testing samples prepared from a piece of Ayresome hæmatite pig iron provided by Mr. L. Gjers :—

Hæmatite Pig Planed.



Average of mixed planings from the whole section.
Sulphur = 0·038 per cent.

Hæmatite Pig Drilled.



Average of drillings mixed together in equal proportions.
Sulphur = 0·039 per cent.

In this pig iron there is very clear evidence of segregation in the centre of the pig, for there is about 45 per cent. more sulphur in that part than in the average of the whole pig.

If drillings be taken from a pig at the points marked on the right of the diagram, and be mixed together in equal proportion, a fair average will be obtained.

In concluding this second communication, considering that the only object of my investigation has been to obtain truth, I hope that what I have written will result in a valuable discussion, so that more light will be thrown upon a somewhat complex subject, and that theoretical errors due to myself or to others may no longer be allowed to remain to hamper future progress and to pose as scientific truths.

A SUPPLEMENTARY PAPER

ON A

NEW PROCESS FOR DESULPHURISING IRON AND STEEL.

By E. H. SANITER.

In coming before you again, at such an early date, with a second paper on the same subject, I am following the advice of our late President, who foresaw the necessity that would arise of placing before you the latest results, in order that the discussion might be "up to date."

In adopting this course, it is my intention to deal with figures rather than with words, although a few of the latter will be necessary. After six months' further experience of the process, I can but confirm what I have previously said.

At the Wigan Coal and Iron Company, a plant has been laid down for dealing with the whole make of a blast-furnace. The plant and general arrangements are as follows:—The sand-bed has been lowered to the ground level; on this level, and in front of the blast-furnace, is a ladle on a carriage: the ladle is provided with tipping gear. This plant cost considerably under £250 per furnace.

The ladle is heated before the first operation, the mixture put on the bottom, a small cast-iron plate being used to prevent the molten metal cutting under the mixture. The metal is then run in, and as soon as the reaction ceases, is tipped into the lowered sand-bed, and the slag raked out of the ladle, which is then ready for the next operation. This ladle treats from 9 to 12 tons at a cast.

The following twenty consecutive results show the amount and regularity of desulphurisation obtained:—

Number.	Sulphur Before. Per Cent.	Sulphur After. Per Cent.
1.	0·248	0·074
2.	0·150	0·064
3.	0·148	0·067
4.	0·095	0·052
5.	0·134	0 059
6.	0·100	0·043
7.	0·168	0·057
8.	0·094	0·048
9.	0·158	0·037
10.	0·124	0·061
11.	0·146	0·051
12.	0·108	0·053
13.	0·190	0·060
14.	0·258	0·047
15.	0·082	0·039
16.	0·097	0·035
17.	0·072	0·037
18.	0·076	0·029
19.	0·092	0·027
20.	0·098	0·025

The cost of materials is fourpence per ton on these charges, and the other costs, including labour and grinding, have been found to be under twopence per ton.

Among many other results obtained in this way, one may be mentioned which was worked at Dowlais, in which the metal contained only 0·64 per cent. of manganese. The sulphur was reduced from 0·40 to 0·134 per cent. which indicates pretty clearly what may be expected from the ladle treatment under ordinary conditions.

In dealing with larger quantities of metal, where it has been impossible to get the metal quickly enough from the furnace to the ladle, it has been found necessary to make the mixture more infusible. In order to accomplish this, it is desirable to replace a portion of the calcium chloride by the more infusible fluor-spar; in this way the time taken for the fusing of the mixture is considerably lengthened, thus obtaining the desired action on the iron.

Good work also continues to be done at the steel-works, where large quantities of sulphurous iron are also treated in the basic open-hearth, and indeed the record has lately been broken with an iron of the following composition :—

Si.	S.	P.	Mn.
0·28	0·96	0·75	0·30

Analysis of Bath when Melted.

Si.	S.	P.	Mn.
trace	0·953	0·55	0·22

Steel made.

C.	Si.	S.	P.	Mn.
0·12	trace	0·07	0·026	0·47

The elimination of sulphur here shown from pig iron to steel is 92 per cent., the steel being of first-rate quality.

The Wigan Coal and Iron Company, at the end of last month, had made over 16,000 tons of basic steel from sulphurous iron, and had treated over 5000 tons of iron in the ladle at the blast-furnace. Besides this, considerable weights have been treated at other works in the country with successful results.

It is interesting, in following up the question of pure iron quality, that is to say, ingot iron from the basic open-hearth furnace, equal in chemical composition and mechanical properties to the best of Swedish bar iron, to give the following analysis of consecutive charges made from white hæmatite pig iron at Wigan:—

Number.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
	Per Cent.		Per Cent.	Per Cent.	Per Cent.
1.	0·11	traces	0·018	0·006	0·11
2.	0·085	,,	0·016	0·009	0·16
3.	0·11	,,	0·020	0·009	0·12
4.	0·07	,,	0·022	0·008	0·08
5.	0·115	,,	0·016	0·008	0·11
6.	0·08	,,	0·020	0·009	0·14
7.	0·10	,,	0·024	0·005	0·16
8.	0·14	,,	0·014	0·004	0·21
9.	0·075	,,	0·020	0·002	0·19
10.	0·085	,,	0·022	0·010	0·21
11.	0·145	,,	0·018	0·007	0·25
12.	0·14	,,	0·015	0·006	0·23
13.	0·10	,,	0·014	0·004	0·22
14.	0·17	,,	0·014	0·008	0·27
15.	0·24	,,	0·015	0·008	0·31
16.	0·21	,,	0·016	0·003	0·30
17.	0·15	,,	0·012	0·002	0·30
18.	0·14	,,	0·013	0·003	0·33
19.	0·115	,,	0·012	0·003	0·17
20.	0·14	,,	0·017	0·003	0·23
21.	0·10	,,	0·014	0·004	0·19
22.	0·16	,,	0·015	0·004	0·32
23.	0·105	,,	0·014	0·010	0·19
24.	0·11	,,	0·014	0·008	0·29
25.	0·36	,,	0·005	0·020	0·55

This steel has been tested in Sheffield for various purposes for which Swedish bar is used, in making the highest class cutlery and tool steels, with marked success. It has also been found nearly equal to the best charcoal iron for conductivity purposes. It welds splendidly. A piece which had been welded was turned, polished, and pulled in the testing machine; it broke clear of the weld, the line of which it was impossible to detect. The mechanical tests of No. 5, in the preceding table, giving a breaking strain of 24 tons per square inch, with 40 per cent. elongation and 77 per cent. reduction of area, being most extraordinary, and equal to or better than most results of tests given by Swedish bars.

The following table gives the average mechanical test of the steel made in the basic open-hearth from sulphury iron at Wigan :—

No.	C.	Si.	S.	P.	Mn.	Length of Specimen.	Breaking Stress.	Elongation.	Reduction of Area.
	Per Cent		Per Cent.	Per Cent.	Per Cent.	Inches.	Tons per Sq. In.	Per Cent.	Per Cent.
1.	0·10	trace	0·049	0·050	0·57	8	23·4	27·8	60·4
2.	0·115	,,	0·053	0·059	0·60	8	24·4	30·1	52·6
3.	0·135	,,	0·050	0·053	0·54	8	25·1	29·6	52·7
4.	0·155	,,	0·051	0·052	0·57	8	25·9	28·5	51·1
5.	0·205	,,	0·041	0·049	0·56	8	27·0	27·1	47·2
6.	0·245	,,	0·053	0·062	0·56	8	29·2	28·2	53·6
7.	0·27	,,	0·044	0·035	0·49	8	29·3	23·5	34·7
8.	0·315	,,	0·062	0·070	0·70	8	33·2	23·0	31·9
9.	0·34	,,	0·043	0·050	0·69	8	33·4	26·2	49·0
10.	0·37	,,	0·054	0·065	0·70	8	33·1	23·3	33·8
11.	0·54	,,	0·056	0·045	0·58	8	39·1	21·8	41·8
12.	0·62	,,	0·040	0·055	0·70	8	48·8	14·0	22·8

It is generally conceded by most authorities that about 45 per cent. of sulphur is on an average eliminated in the basic Bessemer blow; this, unfortunately, is insufficient to allow a highly sulphurous iron to be used with advantage in this process. When, however, my process is applied, the conditions aimed at being similar to those required in the basic open-hearth, a very satisfactory elimination takes place; so much so, in fact, that iron containing nearly 0·5 per cent. of sulphur has been made into steel.

In carrying out the process in the basic converter a somewhat larger quantity of lime than usual is put in, together with about 40 lbs. of calcium chloride to the ton of metal. The blowing proceeds in the usual way, no difficulty whatever being experienced.

The following results show the very efficient removal of sulphur which took place in charges treated by the Lilleshall Co.:—

Number.	Sulphur in Metal Used.	Sulphur in Steel Made.
	Per Cent.	Per Cent.
1.	0·48	0·110
2.	0·40	0·081
3.	0·32	0·076
4.	0·31	0·072
5.	0·276	0·042
6.	0·20	0·056
7.	0·18	0·036
8.	0·20	0·044
9.	0·20	0·025

Comparing these results with ordinary work, we have:—

	Per Cent.
Ordinary working, elimination of sulphur	45·0
Desulphurised charges, elimination of sulphur . . .	78·0

The difference in the elimination recorded being the difference between good and bad steel.

Appended to this paper will be found a report on the process by Mr. G. J. Snelus, which I am sure will be of interest, coming as it does from so high and independent an authority.

In concluding, I take this opportunity of thanking the many who have assisted me with friendly advice and acts in connection with my work in the past few months.

REPORT upon the Saniter Desulphurisation Process.

By George J. Snelus, F.R.S.

I spent two days, February 21 and 22, 1893, in personally examining the working of this process at the works of the Wigan Coal and Iron Company. Every opportunity was afforded me for investigating the process from beginning to end. All samples were taken and carefully labelled by myself, and these were analysed with extreme care in my own laboratory.

I had some ingots from the Siemens cast C. 1134 heated on the second day and rolled into 2-inch billets. These were afterwards rolled into ⅝ round bars, and tested for tensile strength in my presence. The ingots were 12 inches square, weighing 16 cwt. They were heated (from cold) in 1 hour 20 minutes, and rolled off in twelve passes in the roughing rolls and nine passes in the finishing rolls. I was struck by the remarkably fine quality of the steel. I could not detect the slightest flaw or sign of red-shortness in any of the blooms or in the finished billets, although I examined them minutely. In fact, I never saw any steel roll cleaner or better than this did, and the practical tests fully corroborate the analytical results which follow, and show clearly that this process is most effectual in desulphurising the commonest kind of pig iron, to such an extent that the highest class of steel can be made from it. The materials employed are not costly, and there is no difficulty in carrying out the process and in producing uniformly good results.

The process is adapted either for purifying fluid pig iron direct from the blast-furnace, by running the fluid metal into a ladle having a layer of the purifying materials on the bottom, and afterwards running the metal into pigs or plate metal for subsequent use in the puddling furnace, &c.; or the crude sulphurous pig is treated in the basic open-hearth furnace or Bessemer converter with the patented mixture, as in the casts C. 1134 and C. 1135.

Calcium chloride is the purifying material in admixture with lime. This at present costs 35s. per ton packed in iron drums, f.o.t St. Helens or Widnes. It is made by the United Alkali Co. from residues of the Weldon process, and contains 70 per cent. absolute calcium chloride, 1 to 2 per cent. impurities, the balance being water. It is dried in rough iron dishes in a reverberatory furnace before use.

In purifying the metal in the ladle, fluorspar is sometimes mixed with the calcium chloride to retard the process, and some limestone is used to save lime and produce a boil in the ladle. Fluorspar can also be used with the other ingredients, lime, limestone, and purple ore in the ladle, but the mixture is not quite so efficient as when calcium chloride is used.

The pig iron used in these experiments was made from the following burden:—

	Per Cent.
Tap cinder	94·68
Irish ore	4·21
Purple ore	1·11

The analysis of the material showed:—

Tap Cinder.		Irish Ore.		Silverdale Limestone.	
	Per Cent.		Per Cent.		Per Cent.
Iron	53·8	Moisture	14·7	Calcium carbonate	94·0
Manganese	3·0	Iron	21·5	Magnesia	0·6
Silica	16·1	Silica	6·3	Alumina	0·7
Phosphoric acid	5·5	Alumina	30·7	Iron oxide	0·5
Sulphur	0·25	Titanic acid	2·6	Silica	3·2
				Water	1·0

The blast-furnace was running very freely on this mixture; the slag was fluid, and evidently carried off the bulk of the manganese, from the tap cinder. The colour of the slag at the No. 1 experiment was greenish grey, but the temperature of the blast was lowered for the ladle casts 2 and 3, and the slag was turning black.

Desulphurising Fluid Pig Iron in the Ladle.

No. 1 Ladle Experiment.

The following mixture, finely ground and dried, was placed at the bottom of a 10-ton ladle lined in the ordinary way. A piece of cast-iron plate was placed on the mixture where the iron struck. The iron was run from the furnace very quickly, the whole 9 tons 1 cwt. being run in three or four minutes; very considerable boiling took place in the ladle, and dense white fumes escaped from the mixture, but there was no ejection of metal and no trouble. In a few minutes the boil subsided, and the metal was tapped and run into iron plate moulds. It appeared as though considerable heat was developed by the process, for the iron remained perfectly fluid, and there was not the least skull in the ladle.

The mixture employed consisted of—

Dry calcium chloride	90 lbs.
Fluorspar	90 „
Limestone	225 „
Lime	110 „

The metal contained—

	Before Treatment. Per Cent.	After Treatment. Per Cent.
Sulphur	0·230	0·025
Silicon	0·932	0·768

The slag contained—

	Per Cent.
Silica	21·6
Lime	59·13
Sulphur	2·74

Thus there is considerable diminution of silicon and a very remarkable elimination of sulphur, part of which, at least, is found in the slag.

No. 2 Ladle Experiment.

The mixture employed consisted of—

Dry calcium chloride	180 lbs.
Dry lime	200 „

This was rammed into the bottom of the ladle as before, and the metal run on to it rapidly from the furnace. The boiling was not so violent as in the previous case.

The metal contained—

	Before Treatment. Per Cent.	After Treatment. Per Cent.
Sulphur	0·260	0·091
Silicon	0·512	0·442

The slag contained—

	Per Cent.
Silica	23·4
Lime	53·0
Sulphur	2·93

The pig iron contained rather more sulphur in this case, and the elimination, though not so complete, is very remarkable.

The weight of metal treated was 9 tons 12 cwt.

No. 3 Ladle Experiment.

Mixture employed.

Purple ore	120 lbs.
Fluorspar	180 „
Limestone	225 „
Lime	110 „

Metal.

	Before. Per Cent.	After. Per Cent.
Sulphur	·302	·096
Silicon	·745	·495

Slag.

	Per Cent.
Silica	20·60
Lime	53·00
Sulphur	3·91

is case also the elimination of sulphur is very considerable, ing to nearly 65 per cent. of the original quantity. Weight l, 9 tons 14 cwt.

Experiment in the Basic Open-Hearth Furnace.

ɔig iron employed was the same as in the previous experi- ·un into pigs in the ordinary way. The scrap was a mixture inds. Calcium chloride was the purifying reagent. ollowing are particulars of this charge:—

C. 1134.

12 tons white cinder pig iron.
3 tons steel scrap.
1 ton 10 cwt. limestone
15 cwt. purple ore } Charged with the metal.
1 ton 7 cwt. 2 qrs. lime
1 ton limestone
16 cwt. 1 qr. pottery mine } Used for feeding.
7 cwt. of 70 per cent. calcium chloride
15 cwt. of No. 3 common pig (1·5 per cent. P), used for pigging.
1 cwt. 1 qr. 20 lbs. of 80 per cent. ferro-manganese added in steel ladle.
Ingots made, 14 tons 15 cwt.
Furnace full, 11.25 A.M.
Furnace tapped, 10.35 P.M.

netal had all been melted down some time when No. 1 (melted sample) was drawn at 5 P.M.

At 5.20, about 2 cwt. of dry calcium chloride was charged, then more lime, then further 2½ cwt. of calcium chloride.

At 6.10, No. 2 samples of metal and slag were drawn. More limestone and about 12 cwt. of pottery mine were then charged.

At 7.15, No. 3 sample drawn.

At 8.15, No. 4 sample drawn, and about 4 cwt. phosphoric No. 3 pig iron added.

At 8.20, more lime added, then further 2½ cwt. calcium chloride.

At 8.30, 4 cwt. No. 3 pig added. Sample tested for sulphur.

At 9.10, No. 5 sample drawn.

At 9.15, more pig charged. Both samples tested for sulphur.

At 10, sample tested for sulphur.

At 10.35, No. 6 sample drawn and furnace cast.

The followed tabulated statement shows the composition of the metal and slag at the various stages:—

Description.	Scrap.	Pig Iron.	Melted Sample No. 1.	Melted Sample No. 2.	Melted Sample No. 3.	Melted Sample No. 4.	Melted Sample No. 5.	Melted Sample No. 6.	Final Steel.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Combined carbon	...	1·270	0·200	0·090	0·07	0·060	0·060	0·055	0·100
Silicon . .	...	0·186	0·060	...	0·03	0·006	trace	trace	...
Sulphur . .	0·06	0·379	0·320	0·181	0·14	0·129	0·093	0·041	0·040
Phosphorus .	...	2·568	1·075	...	0·591	0·163	0·054	0·027	0·030
Manganese . .	...	...	0·200	...	...	...	...	...	0·504
			P.M.	P.M.	P.M.	P.M.	P.M.	P.M.	
Time . . .	...	...	5	6.10	7·15	8·15	9·10	10·35	...

Corresponding Slags.

Description.	1.	2.	3.	4.	5.	6.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica	18·30	15·00	14·20	12 80	11·60	10·80
Ferrous oxide . .	5·39	3·59	3·79	4·11	5·65	7·19
Ferric oxide . .	3·50	2·60	2·60	2·60	2·80	2·60
Lime	49·24	49·60	50·00	50·94	55·64	57·00
Sulphur . . .	0·315	0·576	0·507	0·480	0·659	0·645
Phosphoric anhydride .	11·75	16·10	19·20	22·49	18·74	...
Alumina . . .	...	6·00	...	4·00	...	...
Calcium chloride . .	...	5·87	...	...	...	3·09

On the second day a second basic charge was watched, and the samples taken yielded the following results:—

C. 1135.

Description.	Pig Used.	Melted Sample.	Final Steel.
	Per Cent.	Per Cent.	Per Cent.
Combined carbon . .	1·50	1·10	0·140
Phosphorus . . .	2·95	1·79	0·027
Manganese . . .	...	0·468	0·518
Sulphur	0·395	0·30	0·046

Mechanical Test of Steel from C. 1134.

Section.	Area. Per Cent.	Reduction of Area.	Reduction of Area. Per Cent.	Elongation. Per Cent.	Breaking Stress. Tons per Sq. In.
¾ round .	0·3068	0·1299	57·6	27·4	23·7

Length of test-piece, 8 inches.

The above analyses show, and all my observations confirm the conclusion, that this is a thoroughly practical, trustworthy, and inexpensive process for desulphurisation, and that by it, using the basic process, white iron made entirely from cinder can be converted into excellent steel without undue waste or loss of time.

DISCUSSION.

The PRESIDENT said that the question of desulphurisation of pig iron was, of course, a very important one for the basic process. The first question one naturally asked was, Why make pig iron so high in sulphur? There seemed to be great trouble and cost involved in getting rid of it. With the present knowledge of blast-furnace working it seemed to be impossible to make iron low in silicon—which was desirable for the basic process—and low in sulphur. He would be glad to learn during the discussion whether it was possible to rely upon the desulphurisation being effected simply by pouring iron on a layer of calcium chloride placed in the bottom of a ladle in the way described. He hoped that in the discussion on the following day those questions would be treated from a practical point of view.

The meeting was then adjourned.

The proceedings were resumed on THURSDAY, MAY 25—Mr. E. WINDSOR RICHARDS, President, again occupying the chair.

The PRESIDENT said that, in discussing the two very interesting papers on desulphurisation, it was desirable to bear in mind that there were two difficulties to contend with. The first was having to use an iron for steel-making high in silicon and low in sulphur. The high proportion of silicon caused great wear and tear of the converter linings or furnace bottoms, and there was also a great waste of metal. The second difficulty was caused by an iron low in silicon and high in sulphur, which removed the first difficulty. But they were met by another, namely, the steel being hot-short, required some process of desulphurisation. He asked, therefore, whether that second trouble, with the extra cost of desulphurising, was not as great as, if not greater than, the first? Was the Saniter process so absolutely trustworthy that it could be left in the hands of ordinary workmen in constant every-day practice? Was there not an intermediate course to pursue, so as to avoid the two difficulties and the complication of a third process? They knew that many thousands of tons of good steel had been made from pig iron not too high in silicon and not too high in sulphur. Was not that intermediate course the best of the three to pursue?

Having known Mr. Stead a great number of years, and having great faith in his work, he would refer for a moment to that part of Mr. Stead's paper which described the Saniter process (p. 67). He would take No. 1, in which the mixture was composed of 350 lbs. of carbonate of lime, and 180 lbs. of chloride of calcium. In the analysis of the crude metal given it would be found that there was 0·148 per cent. of silicon, while sulphur was as high as 0·671, and from those two analyses they would, of course, expect a very small quantity of manganese—0·173. The analyses of the refined metal gave 0·355 per cent. of sulphur, showing an elimination of 47 per cent. only. That was a metal absolutely useless for steel-making. He had asked before, and he would ask again, Why make such a pig iron? Take No. 3, which seemed to be a fairly good pig iron. The silicon was 0·521, the sulphur 0·145, the manganese 1·29 per cent.; the sulphur

was reduced to 0·05, the sulphur removed being equal to 65 per cent. That was satisfactory.

But supposing that pig iron had been taken direct to the Bessemer converter, there would have been an elimination of at least 45 to 50 per cent. in the converter according to Mr. Saniter's own showing, so that the 0·145 per cent. of sulphur would have been reduced to about 0·07—a quantity which gave a very good steel. There were a great many eminent chemists and metallurgists present, and therefore they ought to be able to come to a decision upon the question of desulphurisation. Those were some of the points he wished to direct attention to in the discussion.

Sir LOWTHIAN BELL said that it appeared to him in dealing with the question before them they must do so under two very different aspects. They were invited, in the first place, to assent to the proposition that lime or its metallic base, calcium, could, under certain conditions, remove the sulphur from iron, one of those conditions being that the calcium was to be in the form of chloride of calcium. They were then asked to repudiate that admission by the experiments of Mr. Hilgenstock, and that on the ground that it was impossible that that transference of the sulphur could take place under the conditions described by Mr. Saniter, and verified, as he took it to be, by the experiments of Mr. Stead. Mr. Stead, then, had satisfied himself, and that by a series of experiments conducted with his usual exactness and great care, that certain reactions took place which substantiated the doctrine laid down by Mr. Saniter.

The question was whether it was advisable at that particular stage of the inquiry to go into those minute and, to a certain extent, somewhat obscure chemical details. Perhaps instead of having that very interesting scientific duel fought between Mr. Hilgenstock and his friend Mr. Stead, it might have been well to defer that combat until they were satisfied that the reactions themselves really did take place. Of course he was not one who would attempt to underrate the propriety and the great value of chemical inquiry into the reactions which took place in such cases as those under discussion.

The only question he would ask the Institute to consider, then,

was whether the present moment was exactly the right time to enter upon that portion of the inquiry. He must confess *a priori* that if he admitted that calcium or lime were suitable for removing sulphur from iron, he rather questioned whether he should have looked in the direction of calcium chloride to do the work satisfactorily. But that appeared to him scarcely to be the point between them. He would, however, at that stage remark on the entire difference of conditions which necessarily prevailed between laboratory experiments and those that they had to deal with in freeing iron from any of its impurities, or, in fact, dealing with the question at all upon small samples. He thought that they must all admit that it would be a chemical and physical impossibility for them to imitate on the small scale that wonderful concatenation—if he might use the word—of chemical phenomena which occurred daily and hourly and every minute in the blast furnace. There were many conditions which conspired to interfere with conducting an inquiry upon any such footing.

In the first place, in the one case they had to deal with what he might call microscopic quantities, and in the second place they had to deal with questions of temperature. As they all knew, it was a generally received doctrine that mere mass itself would affect the order of chemical reactions—that was supposing they had an acid, A, and a base, B, and that they had established the fact that there was a very intense affinity existing between those two, they knew quite well that by raising the temperature considerably they might alter the reaction of those two bodies, and that, instead of A necessarily seizing B, by having a superabundance of the latter, the actions might be reversed. Then, again, there was the question of temperature.

He thought he had mentioned upon a former occasion, and in connection with that very question, that he had himself conducted some experiments many years ago on a very large scale. It was true it was not with a view of robbing iron of its sulphur, but it was to enable him by the use of iron to rob a compound of calcium—or rather what he might call an oxy-sulphide of calcium—of its sulphur, which existed in quantities equal to something like 25 per cent. of the weight of the whole. In that he had no difficulty whatever. He had made some thousand tons of sulphide of calcium by fusing what was called soda waste

with oxide of iron, got from the roasting of natural sulphide in the manufacture of sulphuric acid. He invariably found that when the temperature was increased beyond a certain point, instead of any of the sulphur going over to the iron as it had done, the product was pig iron containing next to no sulphur. Therefore he thought it perhaps was rather premature to attempt to disturb by mere chemical reasoning what had been stated by Mr. Saniter.

The first thing they had to deal with was the verification of the fact as to the power of chloride of calcium, or any other compound, to remove the diabolical sulphur. It would appear, upon the face of the papers they had before them, that, whatever he or anybody else might think with regard to the action of chloride of calcium upon melted iron, Mr. Saniter had succeeded, in spite of what Mr. Hilgenstock said, in removing a very considerable proportion of the sulphur from iron. Then, no doubt, followed that to which the President had just given expression. There were a great many things in their philosophy that perhaps they were unable to account for. But first let them verify the fact. He did not say that, after having done that, he could accept all that Mr. Saniter had said of his process; for that time and experience would be required.

He could only say from his own trials, and so far as his own observation enabled him to judge, that when he attempted to remove phosphorus from iron, which was an enemy still more to be feared, he thought, even than sulphur, occasionally his experiments were entirely successful, and at other times they were, to say the least of it, more than doubtful. He believed that nothing but actual experience could determine that question. They had the independent authority of Mr. Snelus, declaring the result of his observation. They were told that at a very small expense Mr. Saniter was about to introduce at the Wigan Works an establishment for carrying that idea into practical operation. Let them, therefore, wait. Let them have it clearly demonstrated before them that chloride of calcium would do that which was claimed for it, and not only that, but that it did it with regularity and certainty. After they had determined that, no doubt it would be a most interesting thing to determine by what series of changes the operation had been carried into effect.

He was using that language not merely as a matter of chemical interest, but as one which might tend, and he had no doubt would tend, to throw very great light on the conduct which they must pursue hereafter. But at present, before they went very deeply into the argument as to whether the thing was chemically possible or not, he would like to have it clearly demonstrated that the results claimed for that particular process could be maintained in actual practice.

Mr. J. P. WALTON said he thought that they were deeply indebted to Mr. Stead for his very important papers on the "Elimination of Sulphur from Iron and Steel." These papers constituted an exhaustive résumé of the state of their knowledge of the matter at the present moment, and enriched as they were by so many laboratory experiments undertaken to get at the right understanding of the reactions which took place in the practical working of the industry with which they were all connected, made their communication to the Institute a fact on which they might well congratulate themselves. He had a few remarks to make on one or two of the points dealt with which might possibly tend to remove a little of the obscurity with which they had hitherto been shrouded.

First, the removal of sulphur from iron in the blast furnace. He was entirely at one with Mr. Stead in the facts detailed in the first paper. Those facts could not have been stated more clearly or more concisely. Turning to the statements made in Part I. on the effect of manganese in the blast furnace, after an interesting account of the views which had at different times been expressed as to the reason why manganese should remove sulphur, Mr. Stead finally gave his own view of the matter in the following words:—"From the above considerations, we may safely grant that the effect of manganese in a blast furnace in removing sulphur depends on a portion of the manganese at first reduced entering the metal, where it combines with the sulphur, and leaving the metal again, carries it off to the slag as sulphide of manganese." He (Mr. Walton) was not prepared to admit that that explanation was sufficiently complete. The action of liquation there dealt with undoubtedly went on in the blast furnace. At the steelworks of the Glasgow Iron and Steel Company at Wishaw

he years ago took advantage of that fact in the removal of sulphur from basic pig iron in the cupola. He admitted fully that "practically all the sulphur charged into a blast furnace in the ore, before it reaches the hearth, must at one time during its descent have combined with the iron;" but his contention was that by far the greater quantity of the sulphur was removed by the lime and not by the manganese. To enable them to follow the action that went on with greater clearness, let them take the case of a blast furnace making foundry iron. The silicon was high and the sulphur low, because the pig was made at a temperature sufficiently high for the lime to seize on and take out the sulphur; but at the same temperature lime was not sufficiently powerful to keep the silica entirely in combination with it, and some of the silicon became reduced, chemically speaking, and entered the pig iron. Making the slag still richer in lime would help to bring down the silicon contents slightly, but if the silicon was to be brought very low it was necessary to reduce the temperature of the blast furnace. The sulphur now began to go up, and a slag rich in lime being very pasty and infusible, there was a danger of the furnace hearth becoming "gobbed up." It was under these circumstances that the value of manganese made itself felt.

It was quite true, as Mr. Stead said, that "when manganese remains in the slag its presence is valueless as a desulphuriser." The value of manganese depended on the fact that a part of it remained in the slag, rendering a pasty, calcareous slag very fluid by the presence of silicate of manganese. Lime was thus left free in a state and at a temperature at which it was powerful as a sulphur remover. Mr. Snelus's explanation was therefore quite correct, with the very important additional consideration of a proper temperature. In other words, for the same silicon contents in the pig iron, manganese when present allowed a higher temperature to be possible in the blast furnace, and the higher the temperature the more active lime was in the removal of sulphur. He did not by any means wish to state that that was the sole action which went on. Before manganese could be reduced to the metallic state, and could enter into the composition of the metal to such an extent as to carry off sulphur by liquation as manganese sulphide, a high temperature must prevail in the fur-

nace, and then the two actions went on concurrently. He now came to examine the cases recorded by Tucker and Harbord, of a comparatively high manganese content existing along with a high sulphur. Manganese and sulphur only were given; silicon and phosphorus had been omitted. If these had been mentioned the explanation would have been more apparent. The manganese content was high, showing that the furnace which made the iron was working hot. How came it, then, that the sulphur was not low? He would tell them, because he had occasionally succeeded in making a similar pig iron himself. This pig iron was basic, he believed, and was made in Staffordshire. Now basic pig iron in Staffordshire was made from a mixture of mill and tap cinders along with C.B. and manganese ores. Tap cinders contained 15 to 18 per cent. of silica; mill cinder contained 20 to 30 per cent. A good deal of these cinders came mixed in the same waggons, being probably taken from an old heap when cinders were simply thrown away. When that particular quality of pig iron spoken of was made, they had had an excessive quantity of siliceous mill cinder in the burden. Possibly also the fuel and C.B. might have been extra siliceous, and as the other components of the burden—namely, the lime and manganese ore—were unaltered, there was neither lime nor manganese sufficient to cope with the extra silica. In other words, the blast-furnace slag had suddenly become too acid, and consequently the sulphur remained in combination with the iron. He was confident that if the content of silicon and phosphorus were given, they would find that the silicon would be higher and the phosphorus lower than in the ordinary run of iron made.

He now turned to the remarks on sulphur in the basic Bessemer process. Most authorities were agreed that there was a considerable quantity of sulphur removed in the basic Bessemer converter. Still there were exceptions, as was proved by Mr. Stead's own experiments at Eston, and also by Mr. Kupelwieser at Hoerde and at Witkowitz. He (Mr. Walton) thought he was in a position to completely elucidate that point. It was merely a question of the purity of the lime used in the operation. A comparatively small percentage of impurities in the lime made a very considerable difference in its power to remove sulphur (much more than one would think from *a priori* reasoning), and increas-

ing the quantity of lime used per ton of pig iron did not give a corresponding benefit. If the lime used were very pure and free from sulphur, the quantity of sulphur removed would be very considerable. If the lime were siliceous, and high in sulphur, sulphur would actually go out of the lime into the steel. Midway between those extremes they might have a lime which would be neutral in action, neither giving nor removing the sulphur. He would give them his experience on this point. In starting the Wishaw steelworks of the Glasgow Iron and Steel Company, some eight years ago, he had, of course, analysed all the local limes, and chosen the purest for their use. Its composition was as follows:—Silica, 2·5 to 3·5 per cent.; sulphur, 0·27 to 0·35 per cent.; and iron and alumina, 2 to 3 per cent. Now, it so happened that the works did not begin quite so early as was expected, and of course the people with whom the contract for the lime had been made had to find another market for it. When the works finally were ready, these people had still got some lime to deliver to their other customers, and without saying anything to him about it, they bought from another burner and sent the bought lime to Wishaw. The works started, and he was perfectly astonished for a shift or two at the sulphur which was found in the steel. There was some sulphurous iron on the place, and at first he thought that by some mistake this iron had been placed on the cupola bank. But no, the cupola metal when examined ran from 0·03 to 0·06 per cent. of sulphur, and yet the sulphur in the steel was running from 0·13 to 0·2 per cent. At last he took a sample of the lime, and saw at once what was the explanation. The first sample he examined contained silica, 5·05 per cent.; sulphur, 0·69 per cent.; and the second sample contained silica, 6·85 per cent., and sulphur, 1 per cent. It was needless to state that that lime was stopped at once.

As he had before stated, the lime ordinarily used contained 2·5 to 3·5 per cent. of silica. That lime was about neutral, and generally speaking there was no reduction of sulphur, but rather a slight increase if anything. Being anxious to try the effect of pure lime, and opportunity offering, he bought a quantity of a very pure limestone (although at a high price) a few months ago, and burnt it in one of the dolomite kilns. The burnt lime analysed as follows:—Silica 0·4 per cent., iron and alumina 0·93

per cent., lime 95·9 per cent., and just traces of sulphur and phosphorus. It would be seen that it was remarkably pure, and, as he anticipated, the effect was most marked. Cupola-metal samples were not taken, but on the same shift the steel from their ordinary lime was running 0·063 and 0·065 per cent. The moment the pure lime went on, the sulphur was reduced from 0·02 to 0·03 per cent., and as soon as the pure lime was done the steels immediately went up to the old figure. He reduced the quantity used per ton considerably, and yet the sulphur did not exceed 0·03 per cent. He repeated the experiment on two or three occasions with the same results. That, he thought, completed the chain of evidence in favour of his opinion that the removal of sulphur in the basic Bessemer converter was entirely a matter of the purity of the lime used in the operation.

It would be observed, however, that he had dealt with this matter purely from a practical point of view. He would come to the theory presently, but wished to mention at this point that a pure lime like that referred to materially lessened their difficulties with both phosphorus and silicon, and while perhaps not having such a marked influence in the basic open-hearth process, was yet efficacious in carrying away sulphur. Mr. Stead would say that those results did not affect his main position, that when calcium sulphide was once formed, the sulphur was not again given up to the steel. He freely admitted that in the case where he got a large addition of sulphur in the steel, the sulphur was undoubtedly present in the lime as sulphate ($CaSO_4$). He had been inclined to the opinion that when sulphur existed in the slag, even as sulphide above about 0·4 per cent., it then began to be reduced and to give a portion up to the steel, if that steel was low in sulphur, so that a slag might remove a considerable quantity of sulphur from a pig iron containing, say, from 0·2 to 0·3 per cent. of sulphur, and yet impart a considerable quantity of sulphur if the pig contained only 0·02 to 0·05 per cent. But his views on that matter had been very considerably modified by the papers presented by Mr. Saniter and by Mr. Stead, particularly by Mr. Stead's second communication. Undoubtedly sulphur, under certain conditions, went into the steel, and most likely the action that took place was that explained by Mr. Stead in his second communication. Too much stress, in

his opinion, could not be laid on the important experiments carried out by Mr. Stead, and the conclusions drawn therefrom, which he thought conclusively proved that the normal condition of a mixture of sulphide of iron and calcium oxide, after being subjected to a heat above redness, was that the sulphur and oxygen had changed places, calcium sulphide and ferrous oxide being formed in accordance with the formula given by Mr. Stead; and that when the sulphur was once combined with the lime, the calcium sulphide so produced was stable, the sulphur not again returning to the metal.

Not having seen Mr. Hilgenstock's communication to *Stahl und Eisen*, he was entirely indebted to Mr. Stead's paper for any account of it, but his theory of a "regular production of calcium sulphate and its decomposition by the iron bath" in the basic Bessemer was, in his opinion, effectually disposed of by Mr. Stead. Any experience that he had had with the Bessemer acid process did not show any reduction of sulphur in the steel. There were thus two good commercial desulphurisation processes available—the Massenez and the Saniter—and the choice of either of them in the basic process would depend on whether the Bessemer or the open-hearth method was employed. Now, as to Massenez's process, that, in his opinion, would be the method of desulphurisation selected by all those who used the Bessemer plant in the manufacture of basic steel, more particularly if they made their own pig iron, for they would have to use direct metal and avoid cupola expenses. It depended for its efficiency on the fact that when metallic manganese was added to molten metal high in sulphur, the manganese combined with the sulphur, expelling the iron, and the manganese sulphide so formed gradually rose to the surface and entered the slag. He long ago took advantage of this fact in the removal of sulphur from basic iron in the cupola, but the Massenez method performed the operation with the minimum of manganese and of expense. Now as to Saniter's process. In this process of desulphurising calcium chloride was employed in conjunction with lime. He took it that the value of calcium chloride was that it formed a very fluid medium, in which calcium oxide was dissolved, so that the continual fresh surfaces of calcium oxide in the slag were being brought into contact with fresh surfaces of sulphide

of iron in the iron, and the exchange of oxygen and sulphur took place in accordance with the very important reaction proved, in his opinion, by Mr. Stead, and the bath of metal was gradually desulphurised. He considered that this method would be the one adopted by all those who used the open-hearth process, as they had an extraneous source of heat and the element of time to help them in the elimination of sulphur. He did not think that the Saniter process was a good one for purifying crude metal.

As Sir Lowthian Bell had already pointed out, they must have absolute certainty of results, and the mere running of molten metal into the mixture of calcium chloride and lime contained in the ladle was not, in his opinion, liable to lead to complete desulphurisation. But, at the same time, it would remove a considerable quantity of sulphur. He had not had an opportunity of carrying out the experiment himself, but he had witnessed an experiment carried out by his friend, Mr. Retchford, of Glengarnock, and there was about 40 per cent. of sulphur eliminated. Direct metal was used, and the blast furnace being a little "off" at the time, rendered the occasion a particularly suitable one for trying the experiment. Three samples were taken while the iron was being run into the ladle, and the average analysis showed 0·156 per cent. of sulphur. Three samples were also taken while pouring from the ladle into the converter, and the average analysis was 0·095 per cent. of sulphur, showing that the metal had been desulphurised to the extent of 0·061 per cent. in the ladle.

Mr. E. P. Martin said that with regard to the chemical side of the question he would leave that to abler hands to deal with. At Dowlais they had tried the Saniter process, and what had taken place there confirmed what Sir Lowthian Bell had said, that the process, with the crude method in which it was carried out, was too irregular. At the same time, he believed that the chloride process did remove a very large amount of sulphur. He thought that the future of the Saniter process had a wider area in dealing with the basic process in the open-hearth furnace. He could only confirm what had taken place, and what had been mentioned in Mr. Saniter's paper, that they sent up some pig iron, containing nearly 1 per cent. of sulphur, to test; that sulphur

as removed down to as low as 0·07 or 0·08 up to 0·1. The whole of the material, with the exception of one cast in which the manganese happened to be abnormally low, worked exceedingly well, and the tests it stood were most satisfactory. He was, however, of opinion, that in dealing with inferior pig iron by the Saniter process, perhaps the best method would be to desiliconise the iron to a certain point in a Bessemer converter, and then to transfer the molten metal to the open-hearth furnace, for the reason, among others, that the value of the slag formed a considerable item in the cost of working, and if into the open-hearth furnace a material was introduced that really required a comparatively small amount of addition in the shape of lime, a slag was produced containing a very much larger proportion of phosphoric acid, and therefore much more valuable. On the whole, he thought that the Saniter process was one well worthy of attention, and as far as they at Dowlais were concerned they intended following it up and finding out what it would do for them.

Mr. W. HAWDON said that in regard to the exactness of the working of the chloride of lime in removing sulphur he could not say much, but as they were makers of basic pig iron at the Newport Ironworks, Middlesbrough, they were naturally interested in the subject, and had had a few experiments tried. It was only fair to state, however, that the vessel in which they tried the experiments was condemned by Mr. Saniter as not being one from which exact results might be obtained. It was an ordinary foundry ladle of fairly large diameter and shallow, whereas Mr. Saniter had pointed out that they ought to have used a narrow and deep vessel, so that the gases might act on the molten metal in a better manner. He had, however, much pleasure in stating the results that they had obtained. Molten iron containing 1·2 per cent. of silicon was put in, and the silicon was reduced to 0·93. The sulphur was 0·06 per cent., and it was reduced to 0·027. Then they had a very hot Cleveland iron, containing 4·14 silicon, which was reduced to 2·4; the sulphur was 0·019 per cent., and it was reduced to 0·013. They tried a white basic iron which was very low in silicon, containing 0·4 per cent., and it was reduced to a trace; it contained 0·19 of sulphur, which was only reduced to 0·12.

These rather irregular results in regard to the sulphur were due, he believed, to a great extent to the vessel, because, as he had said, they had been obliged to use a shallow vessel, and could only try one heat a day; and consequently, though the vessel was warmed up as well as they could warm it with coke, it was pretty nearly cooled when they had to conduct the experiment.

It appeared to him, however, that the Saniter process was well worthy of the consideration of pig iron and steel makers, especially of those who used the metal for puddling. If they could reduce siliceous irons, or the irons which were rather high in silicon for forging—if they could take the silicon out and could make such iron very suitable for forging—then the process was well worthy of their consideration. It had occurred to him that in using a mottled iron the sulphur had always been a trouble with the puddlers, but if they could use the Saniter process and remove the sulphur, then they could have an iron low in silicon, which was very suitable for puddling. The reason which led them to make those crude experiments was that in the Cleveland district they were using as much ore from Spain as they were native ironstone from the mines only six or seven miles off, and if they could introduce a process which would enable them to use more of the native stone and so employ considerably more men, that would be a great benefit to the district.

Mr. F. W. HARBORD said that he considered that desulphurisation was merely a result of a fluid basic slag. The calcium chloride really acted as Mr. Walton had mentioned, and enabled a lot of lime to be dissolved in the slag and to be brought into intimate contact with the metal. He remembered that in dephosphorising at various times he had repeatedly noticed that if they could get a fluid slag rich in lime early, the dephosphorisation was much more rapid in the basic open-hearth furnace. By putting chloride of calcium into an open-hearth furnace, that would enable them to carry a heavier lime burden on the slag without its becoming infusible. This, he thought, was borne out somewhat by the experiments given by Mr. Stead with the Saniter process—in No. 5, for instance, where he used fluorspar and less than half the usual amount of chloride of lime. The

fluorspar would practically act in the same way as the chloride of lime by giving great fluidity and enabling intimate contact between the lime and the metal to be effected.

He was interested in Mr. Stead's remarks about phosphorus and manganese. Several years ago he had found accidentally in dephosphorising in the basic open-hearth furnace, especially if there was little iron oxide in the slag, that a considerable amount of manganese passed from the slag to the metal. Of course they had the reducing agents, carbon and silicon, present as well as the phosphorus, but if the phosphorus could be completely oxidised by the oxide of manganese—that is to say, if the impurities of the pig iron could be completely oxidised by the oxide of manganese—then a man working on a heat with oxide of manganese as the main oxidising agent and using a low iron ore, could get extremely good steel with a very considerable amount of manganese in it. In one case, a friend of his had worked down a change entirely with manganese ore, showing that, at all events, phosphorus was oxidised in the presence of silicon and carbon by oxide of manganese.

Mr. SNELUS thought, in the first place, that the thanks of the Institute were eminently due to Mr. Stead for the great time, trouble, and expense which he had expended in trying to elucidate this very difficult question. He was very glad indeed to be able to entirely endorse the views which Mr. Stead had propounded. He thought that his experiments were quite conclusive on the point that calcium was the chief agent in seizing hold of sulphur. It had long ago unanimously been agreed that in the blast furnace it was the calcium which held the sulphur and transmitted it to the slag.

As he had expressed on previous occasions, the reason for that appeared to him to be that in the blast furnace there was a highly reducing atmosphere, capable of reducing the lime to the state of calcium, and of leaving the calcium free to seize hold of the sulphur, for which it had a greater affinity than had iron itself. He could not conceive that there could be any question as to how the sulphur was removed in the blast furnace. It was well known that the sulphur existing in the blast-furnace slag was there as sulphide of calcium. The moment the slag was

moistened, it was decomposed and sulphuretted hydrogen was given off in vast quantities. The slag, too, became disintegrated in a way that showed that there was a compound that was most easily split up. That being the case, it would seem that the most reasonable vehicle to use to remove sulphur from iron in the processes of steel making would be calcium, but the difficulty was how to get calcium so as to act upon the sulphur during those processes.

He thought, therefore, that great credit was due to Mr. Saniter for having arrived at what he thought would turn out to be an exceedingly valuable plan. There was no question that Mr. Saniter's experiments were now beyond the initial stage. They were now practical operations, and Mr. Saniter had given quite sufficient examples to show that the practical results were certainly to be relied on, when they were carried out in a proper and skilled manner.

Mr. Stead had, he thought, entirely controverted the opinion of the German metallurgists, that oxide of iron was the vehicle which carried out the sulphur, and that the sulphur remained, combined as sulphide of iron. He thought there could be no question that whether it was that those highly basic slags had the power of holding in solution and effectually sealing up the sulphide of iron, or whether it was—given sulphide of iron and calcium in such a condition that an interchange could take place—that that interchange did take place, the fact remained that the sulphur did go into the slag, and that it remained there and was not acted upon by the iron. The balance of all the evidence that Mr Stead had brought forward clearly proved that there was a reaction taking place between the sulphide of iron and the calcium compound, resulting in the formation of sulphide of calcium and in the decomposition of the sulphide of iron, and that that was due largely to the fact that those fusible basic slags, while they were fluid, had the power of holding sulphide of calcium in solution in such a way that no change could take place by the action of the iron. He thought there could be no question, judging from a very careful study of the experiments that had been made, and from the results obtained, that it was possible to remove the sulphur and to transfer it to the slag, and that once it was in the slag it was not again taken up by the iron.

He could not at all follow Mr. Hilgenstock when he suggested that the sulphur in the iron at one time was converted into sulphuric acid. He could not understand the existence of sulphuric acid at those high temperatures. Sulphuric acid must be decomposed, and he could not understand that it was formed in one instance and decomposed in another under exactly the same conditions. He could not conceive for a moment that sulphuric acid was formed in the process. He quite agreed with Sir Lowthian Bell that the conditions of small experiments were sometimes varied when they were carried out on a large scale; but he still maintained that if an experiment was made and a chemical reaction obtained, which could be regarded as absolutely sure on a small scale, and if the conditions of that experiment were repeated on the large scale, the experiment would be more successful on the large scale than on the small. He would refer them to the very early experiments on the basic process in proof of that. His own experiments, as they would remember, made in 1872 with the basic process, were carried out with a little over 1 cwt. of iron to begin with, and finally with 3 tons. Mr. Thomas's experiments were even carried out with a few pounds of material, but no one disputed the reactions that took place in those small experiments, which were now repeated on the large scale, because the conditions of the small experiments were true chemical conditions, and the conditions on the larger scale were similar.

Having had the opportunity of seeing the process described by Mr. Saniter, working on a practical scale, he would again remind the Institute that it was no longer merely an experiment. He was bound to confess that he went there with some fear and trembling. He hardly expected to see the process carried out so perfectly. He thought that it was still in the experimental stage, but he found that it was in full working order, and applied constantly to a blast furnace of ordinary capacity, running in the ordinary way. In fact, the process was going on as a large manufacturing operation. Mr. Saniter, he believed, did not rely upon the desulphurisation in the ladle for the full purification of the iron, and he thought the reason of that was quite clear. In the ladle there was not time enough given to carry out the process to its fullest extent. The ladle process could only be a

partial one, and he would point out that the experiments that he had made and those that Mr. Stead had made, clearly showed that the removal of sulphur in those experiments depended largely upon the agitation of the metal and the contact which they could bring about between the reagent and the metal. It would be noticed that he had shown that where carbonate of lime was used, the boiling of the metal was very much more vigorous, and the amount of sulphur removed larger than when carbonate of lime was not used, and he took it that that was entirely due to the opportunity given for the metal and the slag to re-act upon the metal. For this reason, Mr. Saniter, he thought, did not depend upon the ladle process for fully purifying the iron.

What he maintained was, that if they had a furnace working on a sulphurous iron it was possible, by a very simple and inexpensive process, to clear the iron of its sulphur to such a large extent that the puddler could deal with it without any trouble. If it was required to make steel of it, he presumed that Mr. Saniter would strongly recommend, as Mr. Martin did, that the process should be carried out in the open-hearth, a method that was in constant operation at Wigan—not merely on an experimental scale. He had called the operation that he saw an experiment: he doubted the propriety of the term at the time,—it was simply an examination of a process going on in ordinary working, of daily occurrence, and carried on by ordinary workmen, without the least trouble. He need hardly say that those workmen must be skilled; they required a full knowledge of the process and how to adapt it. He certainly thought that the process was equally applicable to the Bessemer basic process. What was wanted in that case was that the metal and the slag should be in a perfectly fluid condition, that the slag should be perfectly basic, and that the contact should be as perfect as possible.

It was quite evident that in the early stages of the process, as Mr. Stead had said, the slag was not perfectly fluid, and therefore it would readily be understood why the sulphur did not go out in the early stages. More than that, as would be seen from the results of all the analyses, the slag was invariably very highly siliceous at the beginning of the process, and, therefore, not in a condition to seize hold of the sulphur; but directly the slag

became thoroughly basic and the calcium sulphide in a condition to be active, then the interchange rapidly took place, the sulphur left the iron and undoubtedly went into the slag, was sealed up there, and a thoroughly good and trustworthy steel was obtained. He thought the process would be very beneficial to the country. As had been pointed out, there were boundless supplies of ore near Cleveland, and yet imported ore was being used to the extent of nearly half the consumption. The process would undoubtedly benefit all those districts that had a class of ore where sulphur had been a trouble as well as phosphorus. He thought that the basic process was now pretty well brought to perfection, inasmuch as the two great enemies of the steelmaker, the sulphur and the phosphorus, could be removed. He also thought that that process would to some extent assist his own district, the hæmatite district of Cumberland, which he need not say was in a deplorable state. He had often been condemned by his friends in his own neighbourhood for having ruined his own district by the aid which he had given to the dephosphorising process, and he hoped that he would atone a little for that now by the aid which he should give to the desulphurising, because he thought the latter process was going to place in the hands of the hæmatite makers a means of producing the very highest class of steel.

If reference were made to the long series of results tabulated by Mr. Saniter, it would be seen that the samples of steel, 12, 13, 14, 15, and 16—continuous trials, he would point out, not merely taken by selection, but absolutely continuous trials—all showed that it was possible, starting with a pig iron not very high in sulphur, to produce a material which he did not hesitate to say was far superior to the best Swedish iron. Although the old adage affirmed that "it was impossible to make a silken purse out of a sow's ear," it was undoubtedly possible to make a very high class steel from pig iron of very inferior quality. He was very glad to hear from Professor Dewar, that such material as that, namely, pure iron, was going to be of great service to the electrician, inasmuch as pure iron under certain conditions had a higher electrical conductivity than copper,—in fact the Professor went so far as to almost say that under certain conditions, pure iron might have an absolutely perfect conductivity for electricity. As the Professor pointed out, if they had a conductor that lost

nothing by carrying the power, they had made an enormous advance in practical work.

After what the President had shown them with regard to the manufacture of the high-class material at Low Moor by means of careful supervision of the process with adequate skill, he thought that, if the same kind of skill was brought to bear upon the basic process, with the assistance of Mr. Saniter, there could be no question that the success of the operation would be assured. It was quite clear that if they had an incompetent workman he might spoil the best process. He would also point out in connection with the figures that were given in the papers under discussion, that a great many of the experiments were made purposely to see what would be the result of dealing with abnormal quantities of sulphur. Mr. Martin had instanced one where the sulphur was as high as 1 per cent. He need not say that under ordinary circumstances the sulphur that they had to deal with was very much lower, and, he said again, that that process, if applied with reasonable care and with proper experience, was one which would help the iron and steel maker as much as the dephosphorising process had done.

Mr. Henry Webb said he wished to be allowed to refer to the question from a mechanical standpoint. He had used a very large quantity of bars rolled out of billets made by this process. He had found them uniformly good and thoroughly satisfactory; in fact, better than any bars which he had ever purchased which were made by the acid process. They would weld, punch, rivet, case-harden, were soft to turn, clean, and free from laminations. Whether those billets were made by the calcium-chloride process, or by any other, they did not care; if the makers would only give them that quality they would be quite satisfied.

Mr. E. G. Tosh said he happened to be one of those unfortunate hæmatite makers for whom Mr. Snelus had shown so much sympathy. After hearing Mr. Saniter's paper read at Liverpool at the autumn meeting last year, he went home and made some experiments. They were ladle experiments, the iron being melted in the cupola. The special object which he had in view was, in the first place, to test the accuracy of the method,

and, in the second place, to endeavour to utilise what was in the hands of hæmatite makers at the present time a practical drug, namely, forge iron. Of course, the puddling process having shrunk to such very small dimensions, the sale of the lower grades of hæmatite iron was a matter of great difficulty, in fact, it was almost impossible. He commenced with the grade of iron known in the Furness district as No. 5, which, upon analysis as it ran from the cupola, showed 0·32 per cent. of sulphur. The bottom of the ladle was fettled, so to say, with chloride of calcium, which they manufactured themselves from crude hydrochloric acid neutralised by limestone. No doubt as crude hydrochloric was used, a very large proportion of sulphur was introduced into the mixture, which, according to one of the previous speakers, ought probably not to have been there.

But, to conclude, their experiments were without result at all as far as the elimination of the sulphur went. The 0·32 in the iron which they commenced with was not reduced by more than three or four hundredths, so that the iron after it had gone through the Saniter process—it might have been improperly conducted by them, no doubt it was so—did not show any substantial reduction of the proportion of sulphur in the impure iron. He attached very little importance to his own results, and he would not have spoken had he not heard remarks made in certain quarters as to the untrustworthiness of the process. He attributed his failure at the time to the low percentage of manganese in the iron, hæmatite irons of the north-west district as a rule not containing more than 0·2 per cent. of that element. Having heard the remarks as to the necessity of using pure materials, he should go back prepared to try again; if the experiment should succeed, undoubtedly they would be able, in the hæmatite district, to produce from the lower grades of iron a pure and excellent metal low in silicon.

He should like to add that when the experiments were being made, the evolution of both sulphurous acid and hydrochloric acid was most marked.

Mr. T. M'Leod Percy said, that having been identified with Mr. Saniter at Wigan in his experiments, and latterly in carrying on the process on a much larger scale, he could testify to the

efficiency of the process in eliminating sulphur. The experimental stage had long been passed. At Wigan something like 18,000 tons of steel had now been made in the open-hearth furnace from pig iron containing sulphur from 0·10 to 0·35 per cent. Of course it might be asked why pig iron so high in sulphur should be made; but the difficulty was now that, with the mixture used, they could not make pig iron low in sulphur without the aid of manganiferous ore, and that they found that in taking off the manganiferous ore they were put to a very great disadvantage in making the pig iron which they formerly made: hence they had now adopted the Saniter process. The steel made from it had been sent out to different parts of the country for engineering work generally, for wire, and for forgings, and he had no hesitation in saying that their analyses and the mechanical tests of the steel made would bear comparison with those of any other steel made from pure pig iron. With regard to the remarks made by Mr. Martin, he went down to Dowlais with Mr. Saniter, and could say that every facility was offered them there to experiment with metal direct from the blast-furnace. No doubt they had some irregular results. He was not quite prepared to say why those results were irregular, but he thought that with a little more practice those difficulties could be overcome. He was sorry that Mr. Saniter was not present, as he would have been better able to discuss the matter than himself, but unfortunately that gentleman was ill. At Wigan they had looked upon this process as a decided success, both in the open-hearth and when taking the metal direct from the furnace. They had treated in the blast-furnace between 6000 and 7000 tons of direct metal. They had sent it out into the market as basic pig iron; it had been treated either in the open-hearth furnace or by the Bessemer basic converter, and it had given every satisfaction; therefore he thought they had a right to assume that at Wigan, at any rate, the Saniter process had met with success. The process would be very useful in Staffordshire, where tap-cinder abounded. It would render available a pig iron of a very cheap character, and render it possible, as Mr. Saniter had stated, to produce steel of the very highest quality from very inferior metal. He did not know that he could add very much to what had been so ably stated by Mr. Snelus. When Mr. Snelus was at the

works he had every opportunity presented to him, as he had informed the Institute, of investigating the process; and after the very able remarks of Mr. Snelus there was very little left for him to say.

The PRESIDENT asked Mr. Percy, with reference to the samples 1 and 2 mentioned in Mr. Stead's second paper, if he often made iron so high in sulphur, because the elimination was only about 47 per cent., and 33 per cent. in Nos. 1 and 2. He supposed Mr. Percy did not recommend iron so high in sulphur as those two samples.

Mr. PERCY said he did not. At Wigan, of course, they had sometimes a furnace working badly. Their furnaces, like other furnaces, did not work altogether uniformly. Mr. Stead arranged to visit the works and to experiment with the process; but unfortunately when he arrived their furnace was not working altogether satisfactorily; but Mr. Stead determined, and he (Mr. Percy) agreed with him, to see what could be done with a pig iron very high in sulphur. From that day to this they had not made pig iron of that character, nor did they care to make it.

Professor HUNTINGTON asked whether information could be given as to the value of the slag obtained by the process. The only point which had been considered during the discussion was the value of the steel and of the pig iron; but as the slag in the basic process was of very considerable value, it would be, he thought, very interesting to know whether the chloride of calcium had any detrimental effect or otherwise, when used for agricultural purposes.

Mr. PERCY said the slag was in great demand. They had now worked the process at Wigan for something like twelve months, and he thought if there had been any reason to complain of the character of the slag, they would have heard of it before now. The slag was in such great demand that they had no difficulty in selling it. He believed that Mr. Stead had already made experiments on a small scale with some green-house plants in his own garden, and perhaps that gentleman would state the results.

Mr. STEAD, in reply to the discussion, said that some of the speakers had pointed out that the objection to the Saniter process was the irregularity in the results. Now one of the most astounding things about the process was that in the trials described it had been possible to get out 60 per cent. of sulphur in such a crude way. What were the possibilities of the process if they applied it in a mechanical way? They would undoubtedly be very much better than they were now. A very wide-bottomed ladle, with a thin layer of powdery material on the bottom, was not the best condition in which, theoretically or mechanically, to get intimate mixture between two substances. Supposing that trials were made to find the effect of oxide of iron upon fluid iron by putting the oxide in the ladle in the same way, how much phosphorus would they get out? About 1 per cent. perhaps of the total, and it would be a very irregular result, and every experiment would vary. But because they could only get a very small proportion of the phosphorus out, would they say that oxide of iron was no good? They knew that oxide of iron did remove phosphorus. Only bring the conditions together which favoured the thorough intermixture of the oxide with the fluid iron, and they would get a very perfect elimination of phosphorus. Mr. Snelus had pointed out, and he fully confirmed him in that, that if the metal boiled very thoroughly with the mixture in the ladle, there was a more perfect elimination of sulphur than when it was very quiet. That led them up to one cause of irregularity in the process, which was that the metal, if it was very cold from the blast-furnace—that was, if it was low in manganese, low in silicon, and low in carbon—was rather sluggish. It had not got the life in it that hotter metal had, and consequently it did not boil well, and there was not that intermixture made which always occurred with hotter material. That was one of the causes of irregularity. If mechanical or other means could be used to effect intermixture when the metal was sluggish, the sulphur would in all probability leave the metal. He was afraid that some of his friends had imagined that in making the remark that the Saniter process was "likely to be useful" he was therefore condemning the other process in the mixer. That was not the case. He had never done anything of the kind. There was plenty of room for both processes, and he was quite certain, just as he had been six months

ago, that the Saniter process would be a valuable one for manufacturers of iron *in certain directions*. He had no doubt that the mixer process—the manganese process—would be used very extensively; indeed it must be, for the mixing of the metals was of great importance apart from the desulphurising effected in the mixer. But there was, he believed, a place where the Saniter process could be introduced. Sir Lowthian Bell had made some remarks upon crucible experiments. Now he (Mr. Stead) himself was strongly in favour of crucible experiments, and he thought Sir Lowthian Bell was also, at least upon what were the equivalents of crucible experiments. Where would all our knowledge about blast-furnaces have been if it had not been obtained in the laboratory of Sir Lowthian Bell? How could they have understood the complicated changes that took place in the blast-furnace but for those experimental results obtained in little porcelain tubes, in little crucibles, in small vessels? We should have been without the knowledge. When a new process was brought forward, they wanted to find out all the chemical changes which took place; they could not make experiments on a large scale, and they were obliged to go to the laboratory to make experiment after experiment there. He could tell them that the production of his papers had meant his making ten times the number of experiments that were recorded in it, and that meant a very large amount of work. The matter was not taken up lightly, he could assure them. When he commenced to study this question of desulphurisation, he thought he had a small molehill to go at, but he had no sooner got into the fringe of that molehill than he found it was a very large mountain indeed. Unfortunately he had not got halfway through it before he had found that some of his best friends in Germany were on the top of that mountain, and that it was necessary to criticise, perhaps a little severely, theories which they had advanced, but he hoped that no ill-feeling would be caused.

In regard to Mr. Tosh's experiments, that gentleman said that he observed a very strong smell of sulphurous acid and hydrochloric acid. If sulphurous acid came off, there must be an elimination of sulphur.

Mr. Tosh said he had suggested the source of the sulphurous acid.

Mr. STEAD said that if sulphurous acid was given off in those large quantities, the slag must have been pretty considerably saturated with silica, which had probably been derived from the limestone or from the ladle. The question Professor Huntington asked was a very important one indeed, whether the chloride of calcium was harmful to vegetation? The quantity actually left in the basic slag at the termination of the basic process was exceedingly small, and, without making any investigation whatever, he should have been inclined to believe that such a minute quantity was immaterial. But for all that, they could not accept anything without proving it. Theory was all very well in its place, but they wanted solid fact. In order to ascertain whether the chloride of calcium was injurious, he tried to get information from other sources, but he had not been able to ascertain from any written authority whether the chloride of calcium was really very injurious or not in a small quantity. He therefore watered a portion of the lawn in front of his house with a 2 per cent. solution of chloride of calcium for about a week during the recent dry weather. He also watered another strip, alongside of the first strip, with water containing no chloride of calcium. The experiment had only continued for a week, but he had not seen the slightest difference in the growth of the two strips of grass. A 2 per cent. solution of chloride of calcium would be a very much stronger solution than would come from a very small quantity of basic slag distributed over the land. The next experiment he tried was a little more severe. He soaked a lot of garden peas in chloride of calcium solution of strengths varying from about 1 per cent. up to 5 per cent. He thought that if chloride of calcium was very injurious to germination, the absorption by the peas of such a large quantity as 5 per cent. would perfectly prevent germination. As a matter of fact, the peas that were soaked in water alone, and the peas that were soaked in a 5 per cent. solution of chloride of calcium, and those that were soaked in a 2 per cent. solution, and in a 1 per cent. solution, all germinated and sprouted in the same way. The same seeds after germination were planted in soil and were watered with a 2 per cent. solution of chloride of calcium, and were compared with seeds treated with water alone. The difference was very marked, for the growth of the former was

...ch retarded, and eventually 50 per cent. of the plants died. Those which were not killed grew vigorously after the calcium ...oride solution was replaced by water.

To ascertain the effect on plant life of basic slag from the ...en-hearth Saniter process compared with the effect of ordinary ...sic slags, two batches of carefully prepared soils were mixed ...spectively with 5 per cent. of the two phosphates, both of which ...ntained about the same amount of phosphoric acid, but differed ...a calcium chloride, that from the Saniter process containing ... per cent., the ordinary containing none.

In each of these soils there were sown oats, wheat, barley, and peas. The results at the end of a fortnight showed no difference in the two series of plants. It would appear that chloride of calcium behaves like common salt, that it does not destroy the germ of life in the seed, but when present in large quantity in the solid probably prevents the healthy life of the microscopic organisms which are known to be necessary to prepare the nitrogen in such a condition as to be capable of assimilation by the roots of the plants.

In conclusion, he must acknowledge most kindly the compliment which Mr. Snelus had paid him, and he could assure them that it gave him the very greatest pleasure indeed to receive any compliment from a gentleman whom he considered as his old master in metallurgy.

Mr. E. H. SANITER, in reply to the discussion, wrote that the President in his opening remarks questioned the advisability of making sulphurous iron, and suggested a middle course between high silicon and low sulphur; but it was a well-known fact that, no matter what precautions were taken, blast-furnaces would sometimes make sulphurous iron, and it was then that the absolute necessity of desulphurising arose to prevent the manufacture of red-short steel. It was also cheaper, as he had previously pointed out, to make sulphurous iron, and that remark might be applied not only to the manufacture of basic iron, but also to hæmatite iron for the acid process.

In referring to Mr. Stead's figures, the President asked why ... so high in sulphur was made. Of course no one wished to ...e such iron, but it was made occasionally, and although the

ladle treatment was not successful in reducing it to the required limit, this iron was desulphurised to a further extent in the basic open-hearth, and made into very good steel. The President then referred to No. 3 of Mr. Stead's figures, and pointed out that very good steel could be made with about 0·07 per cent. of sulphur from this iron, without the preliminary desulphurisation. That percentage of sulphur would not meet the specifications of many engineers, but, had the desulphurised metal been used in the converter, the steel, by the same reasoning, would have contained only 0·035 per cent. of sulphur. He would also call the President's attention to examples 1 and 14 in his paper, where the sulphur was reduced from a quarter per cent. to 0·07 and 0·04 respectively. After converting into steel the metal should have contained only 0·035 and 0·02 per cent. of sulphur, but, had the iron treated been used direct in the converter, worthless steel containing 0·12 per cent. of sulphur would have been made.

In reply to Sir Lowthian Bell, he would point out that the results obtained on a few grains of iron in crucibles, set forth in his first paper, had been fully borne out in practical experience on masses of twelve tons of molten iron. The Wigan plant mentioned by Mr. Snelus had already, at the time of the meeting, been working for five months, thousands of tons of iron having been treated. The twenty consecutive results given showed a regular and efficient removal of sulphur. The process was carried out, as stated by Mr. Snelus, by ordinary workmen using an ordinary amount of care.

A few words of explanation were necessary as to the irregular results mentioned by Mr. Martin in the Dowlais trials. These trials were made on hæmatite iron in the molten metal ladle, which was then conveyed to the steel-works and the metal blown in the acid-lined converter. The sulphurous slag, which was in most cases poured into the converter along with the metal, was the cause of the irregularity. Sometimes the sulphur returned from the slag to the steel, at others it did not, the reason for which was difficult to explain. He had no hesitation in saying that charge after charge could be successfully desulphurised in the ladle, but it was absolutely necessary to separate the slag from the metal before attempting to use the metal for steel.

In the clear and exhaustive remarks of Mr. Snelus there was

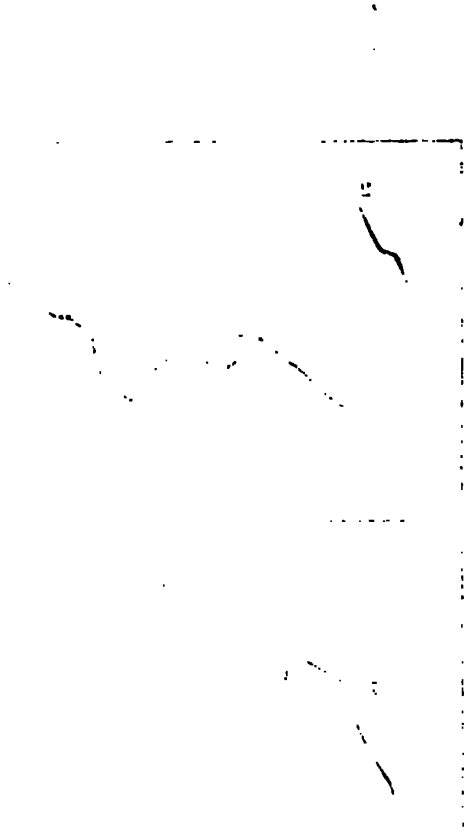
ne point to which he wished to refer more particularly, as it had een mentioned by other speakers. He (Mr. Saniter) did not dvocate the use of the dual process except under exceptional ircumstances. By the dual process he meant a preliminary reatment of the pig iron in the ladle, and a further desulphurisa- ion in the steel furnace. He found that so long as the pig iron as not semi-fluid the ladle process would treat anything up to ·30 per cent. of sulphur, while, as Mr. Martin had pointed out, on containing 1·0 per cent. of sulphur had been made into good teel in the basic open-hearth without any preliminary ladle reatment.

No doubt the evolution of sulphurous acid experienced by Mr. Tosh was due to the large amount of sulphuric acid in the impure cid used. There was no doubt that with pure materials and roper manipulation he would obtain good results. That the bsence of manganese was not the cause might be seen from the esults given in the paper, obtained with a Dowlais iron contain- ng very little manganese.

The PRESIDENT said that they had had two most interesting apers, and a very valuable and interesting discussion, and he was ure the members would give a hearty vote of thanks to Mr. Stead nd to Mr. Saniter.

The following paper was then read :—

.M.A



.M.A

some curves were plotted, giving the results of measurements of the temperature of the hot-blast supplied to certain furnaces. He also described a novel application of the thermo-junction to the indication of the *time* at which the successive charges were introduced into the furnace. For this purpose a thermo-junction, connected with a suitable galvanometer, was placed in the "down-comer" of the blast-furnace, and, as the lowering of the charging cone or bell was attended by the admission of cold ore, the consequent lowering of the temperature could be observed on the galvanometer scale, and enabled the time at which the charging had been effected to be noted by an attendant. In this case the thermo-junction was used merely as a *thermoscope*, and it will, of course, be easy to devise an electrical method of recording the periodic lowering of the charging cone without having recourse to pyrometry.

As regards the measurement of the temperature of the blast, photography has already done excellent service in affording the author of this paper a means of recording changes in the behaviour of alloys during thermal treatment. It was evident that it could also be employed for autographically recording the changes of temperature either in the hot-blast, or in any locality in which the thermo-junction might be placed. The recording pyrometer, described at the last meeting, was accordingly devised, mainly in answer to a request made to the author of this paper by Mr. E. P. Martin, and the first instrument made was naturally, therefore, offered to him for use at the new Dowlais Works at Cardiff, which are under his direction. In the discussion which followed the reading of its description, the President observed that Mr. Martin would soon be in a position to furnish an opinion as to the efficiency of the apparatus, and in the present paper an attempt is made to supply the information which Sir Frederick Abel anticipated would be forthcoming.

Mr. Martin made preparations on a most liberal scale for the installation of the instrument; no less than 360 yards of wires were laid down for connecting the furnaces with the galvanometer, and the thermo-couples were, in the first instance, introduced into the horse-shoe main of a blast-furnace.

The mode of inserting the thermo-junction is a matter of some importance, and it was determined to adopt the form of tube and

gland, devised by Mr. Charles Bell, and used by him with success in the hot-blast mains at the Clarence Works. The initial difficulties inseparable from a new installation were soon overcome by the energy of one of the author's own students, Mr. R. C. Styles, who received the utmost encouragement and aid from Mr. James, the manager of the Dowlais Cardiff Works.

The anticipation that the "recorder" would prove to be a valuable adjunct of an iron and steel works was amply justified, as the curves obtained by its aid will show. These are now submitted, by Mr. Martin's permission, to the members of this Institute. Plate VII. represents a record for 23½ hours of the temperature of the hot-blast supplied to a furnace by a series of stoves, numbered respectively Nos. 1, 2, 3. It is a typical record, and, as it represents an excellent example of careful and successful gas-firing, it may be well to describe it in some detail.

It will be seen that the record begins near the top right-hand corner, and shows that the temperature of the blast contributed by No. 2 stove (at 10 A.M. on the 14th of February) had an initial temperature of 1160° Fahr. At the end of an hour the temperature of the blast had fallen to 955° Fahr., and the gas-man considered that the time had arrived for effecting the connection with a fresh stove, No. 3. As will be seen from the record, this stove contributed blast at an initial temperature of nearly 1230° Fahr., and the temperature fell in the course of 1 hour 50 minutes to 1020° Fahr., when the blast from No. 1 stove was introduced into the horse-shoe main. Inspection of the curve will show the successive variations of temperature. The record, viewed as a whole, shows that the temperature never rose above 1400° Fahr., or fell below 950° Fahr. This record shows good, conscientious, careful firing, such as should ordinarily be obtained in works. Complications are, however, introduced by untoward accidents, which, unfortunately, will happen, and diagram No. 2 has been specially selected as indicating the existence of a set of conditions which presented much difficulty.

The record refers to stoves Nos. 4, 5, 6, 7, and begins at 10.30 A.M. on February 25th. For 2½ hours the temperature of the blast rapidly varied between 1180° and 730° Fahr., and it is

evident the working of the furnace showed that it had a "scaffold," and cold or "coddled" blast was freely introduced. This state of things continued for three hours longer, when the conditions became more equitable. It will be observed that when No. 6 stove is resorted to, the temperature suddenly rises, although it is evident that cold-blast was being used. Stove No. 6 soon gave place to No. 7, and the turn of No. 6 did not come again until seven hours later, when its temperature proved to be very high (1570° Fahr.), and the same fact was recorded when No. 6 stove was again used at 7.10 A.M. on the following morning, and a consideration of this unsatisfactory record led to the view that No. 6 stove must be receiving a supply of hot, and not entirely of cold, air during the period it was being heated up. It was found on investigation that the valve of No. 6 was leaky, and that hot air from the other stoves could find its way into it; an accident which was of course soon remedied.

The importance of a constant temperature of the blast is manifest. The ratio that the reducing actions bear to the fusing ones varies with the temperature of the blast, and if a furnace has been steadily working at a given rate, it will be prejudicial to suddenly increase the activity of reduction in the cooler parts of the furnace, as they would then contribute reduced iron and pasty slag at a greater rate than that at which they could be disposed of in the zone of fusion. The effect of a rapid increase in the temperature of the blast influences the reducing zone more rapidly than it does the zone of fusion, hence the tendency of the furnace to choke if the temperature of the blast is suddenly augmented.

It appears to be recognised that an unduly high temperature of the blast is favourable to the formation of scaffolds, and the introduction of cold-blast is known to remove them.* Hence it is desirable not only to be able to measure the temperature of the blast, but to be able to observe the temperature at any given moment. In recent forms of the "recorder" a subsidiary mirror diverts the ray of light from the drum, and throws it on to a divided transparent scale on the top of the camera, so that a direct observation of the temperature can be made without seriously interrupting the progress of the photographic record. By watch-

* Van Vloten, *Stahl und Eisen*, vol. xii. p. 114.

ing the progress of the record it is frequently possible to diminish the amount of fuel charged into the furnace, and thus to effect economies which may, it is hoped, attain considerable proportions.

If in a given set of conditions 18 units of carbon are required to smelt a ton of iron with the temperature of blast at 880° Fahr., 16 units of carbon will still be required if the temperature be 1660° Fahr., so that there is clearly a limit to the advantages of heating the blast. A large blast-furnace smelting iron may have a capacity of 35,000 cubic feet, and of this 20,000 cubic feet is in brilliant ignition, and presents the largest mass of fuel in rapid combustion which is employed in any single industrial operation. In view of all the complex problems involved in the working of a blast-furnace, the solution of which depends mainly on thermal conditions, it is truly remarkable that hitherto there has been no sustained effort to accurately measure and record the temperature of the blast, this being the factor of paramount influence, and the one that can be most readily controlled.

The chief advantages which may be claimed for the appliance are as follows:—

1. A check is placed on the gas-men, and, to a less extent, on the men at the furnace top.

2. Inferences may be drawn as to the conditions which prevail in the interior of the furnace.

3. Accurate information may be gathered as to the time of reversal of the valves, and of casual admission of cold blast.

4. Certain indications, afforded by the curves, show that changes have been effected in the accessories of the blast-furnace, such as the removal of tuyeres, alterations in breast-plates, &c., &c.

It should be observed that the appliance is popular with the workpeople, who find that regularity in conducting the details of the various operations means increased output, and, moreover, the gas-men recognise that it is to their advantage to have an autographic record of the way they have done their work.

Since this paper was in type, the author received the following letter from Mr. Martin:—

"DOWLAIS, GLAMORGAN, 17*th May* 1893.

"MY DEAR ROBERTS-AUSTEN,—In accordance with the wish expressed by the President at our Liverpool meeting, I have very great pleasure in bearing testimony to what I believe to be the very valuable service rendered by your Recording Pyrometer.

"After the initial difficulties connected with the installation of the new instrument, it has proved to be most useful.

"The accurate measurements of high temperatures will, I feel sure, establish a new era in the management of iron and steel works, and I am very glad indeed that this new application of physical methods to industrial work should have been inaugurated at the Dowlais Cardiff Works.

"I feel that this instrument will sooner or later be applied to the solution of other important physical problems connected with iron and steel making. Possibly important results may be obtained later on by its application to recording the temperature at which steel is cast from the ladle into ingots or moulds, as I have reason to believe that this point has a great deal to do with explaining to some extent some of the uncertainties and difficulties met with in the behaviour of steel when finished.—Yours very truly,

"EDW. P. MARTIN.

"Professor W. C. ROBERTS-AUSTEN, C.B., F.R.S.,
"Royal Mint, London, E.C."

DISCUSSION.

Mr. E. P. MARTIN, on being invited by the President to take part in the discussion, said he had nothing to add to the valuable paper which had been read by Professor Roberts-Austen, except to say that he was very well satisfied with the instrument, that he had ordered another, and that probably that would be followed by a third.

Mr. J. ADAMSON said that after the Liverpool meeting he had communicated with the author to inquire whether the instrument was commercially practicable, and the reply was that at that time it was not; but he (Mr. Adamson) now hoped that it was, because of all things connected with the blast-furnace in modern works, the temperature of the blast seemed the most essential. They had heard from Mr. Martin what they could do at Dowlais with their splendid works, but others could scarcely hope to do the same thing. As far as his experience went (which was very limited), there was more of the second diagram in most iron-works than of the first. He should be very glad to know that it was possible to obtain such an instrument to attach to their plant, and to obtain a continuous record instead of the intermittent one of the Siemens or Hobson pyrometers, as at present used.

Sir LOWTHIAN BELL said that perhaps Professor Roberts-Austen's diagrams gave undue prominence to the inconvenience resulting from variations in the temperature of the blast. No doubt it was much to be desired that the air entering a blast-furnace should be as regular as possible, although it seemed to him that a couple of hundred degrees did not, when continued for a short time, necessarily greatly lower the temperature of the hearth, because the materials came down to the tuyeres impregnated with the heat absorbed from the blast at its normal temperature.

These observations were not made with a view to depreciate the great value of having so admirable an instrument to ascertain

even slight variations of temperature in the vast volume of air entering the furnace, particularly now it was constructed to record its indications.

The inconvenience of any instrument that had hitherto been used was first the untrustworthiness of the indications. Twenty years ago he had an electric instrument devised by Sir William (then Mr.) Siemens for obtaining the temperature of the blast by the retardation which a heated wire offered to the passage of the electric current. Unfortunately it was constructed on far too delicate lines to be of any real value, and it speedily fell into desuetude. They then adopted the plan, recommended by Mr. Siemens, of heating a copper cylinder; but in point of fact its indications were something like five or six minutes before the actual time at which the observation was made. Besides that inconvenience, the observation took a long time. Although that appliance was in extensive use in the Clarence Works, it was not one of which he was particularly enamoured, and from time to time he had himself sought to devise some better mode of obtaining the temperatures. Fortunately, however, M. Le Chatelier and Professor Roberts-Austen had produced their pyrometer.

The instrument, he thought, had a greater value than that of ascertaining the temperature of the blast, namely, that of recording the temperature of the escaping gases; because besides a high temperature there was a loss of fuel. At the Clarence Works there was a variation of from 300° to 700° in the temperature of the escaping gases—he was speaking not from a few observations, but from a continuation of a month's observations taken every day; and that loss—for loss it was—would continue as long as ever the present vicious mode of filling the furnace was continued. The operation of supplying is performed in an interrupted manner, and when discontinued the gases steadily increased in temperature; they rose from the minimum point given by his son in his paper, to which Professor Roberts-Austen had referred, until they got up to 700°. He had calculated what the difference was in a furnace voiding its gases at about 350° to 400°, and what it was at 700°. With the volume of gas given off at those two temperatures the loss amounted as nearly as could be ascertained to ¼ cwt. of coke to the ton.

Mr. R. A. HADFIELD desired to bear testimony to the valuable character of the pyrometer described by Professor Roberts-Austen, and to ask him whether he thought it could be usefully applied to annealing purposes, so as to indicate the range of temperature in several furnaces together, and what the cost would be. He wished also to ask Mr. Martin if he had any difficulty with the thermo-couple. They had some trouble in this respect with the pyrometer used in their own works. The couples became very brittle after working a certain time. He wished to know whether it would give uniform readings, and whether the instrument as recently improved could be rendered more free from the trouble experienced with vibrations. He had had some difficulty in his works in getting a place where that trouble could be avoided. It was important for steel-founders to have the means of indicating exactly the temperatures of annealing furnaces. Now-a-days steel-founders were expected to get material of very high quality as regards ductility. Instead of 8 or 10 per cent. elongation, they were now asked to supply castings with 15 or 20 per cent., and even higher. It was only by paying special attention to the annealing process that they could obtain these qualities. They were all greatly indebted to Professor Roberts-Austen, who was helping them so much in the accurate study of temperatures—a matter of great importance in dealing with a metal like steel, which was so sensitive to molecular changes.

Mr. SNELUS said he wished to thank Professor Roberts-Austen for the admirable way in which he had perfected his very delicate pyrometer. When the first exhibition of the instrument was made, he very much doubted whether it would be possible to adapt it to the requirements of ironworks. From what he had seen, however, he thought it was perfectly possible, and that it would render very great service to the iron and steel maker. He had paid a good deal of attention to that part of the subject, and confessed his disappointment at never having been able to determine satisfactorily the temperature, particularly the continuous temperature of the hot-blast. There could be no question that it was one of the most important points connected with blast-furnace management; and now that an instrument was available that would from hour to hour and from minute to minute tell its own

tale, independently of everybody, he thought they ought to be very grateful to the gentleman who had spent so much time and trouble in perfecting it.

The PRESIDENT wished to call Professor Roberts-Austen's attention to the fact that it was as important to know whether the furnace was regularly charged as whether the temperature of the blast was equable. If he would turn his attention to that point, it would be found to be equally important.

Professor ROBERTS-AUSTEN said he would reply to one or two points, chiefly those raised by Mr. Hadfield. He had asked whether the pyrometers were durable. If they were covered up by porcelain tubes, or, as suggested to him by Mr. Stead in conversation, by a cap of zirconium, or of some material that did not actually touch it, but was sufficient to keep the particles of material projected on to the red-hot pile away from it, he found that they would last many weeks. They did occasionally become brittle and broke, but it was merely necessary to pull out an inch more wire, take off the defective part, and twist it together again —it wanted no soldering—to start fair. Taking one length, say one metre of wire, the records were practically uniform from any portion of it. The question of vibration was no doubt a difficult one, as it was quite likely that it might seriously impair the usefulness of the appliance in certain works, but he thought that by allowing the instrument to stand on a pedestal free from the ground, and by interposing india-rubber plugs, as was done in case of assay balances, it might be got over. When Mr. Adamson wrote to him after the Liverpool meeting, he felt bound to say that, as a matter of actual industrial use, the appliance had not been tried. He now thought that it might be confidently placed in the hands of any one. His efforts would be immediately directed to rendering it recording without the aid of photography, and numerous experiments were in progress with that object in view. His own feeling was that if in works they did not choose to use the extremely delicate means afforded by photography, they hardly deserved to have the appliance at all. Still, that was only his personal view, and he felt bound to provide an instrument which would record, either by pen or pencil or by chemical means,

the actual variations in the blast. The cost of the appliance was at present about £23.

With regard to the introduction of the apparatus into annealing furnaces, he was glad to say that steps were being taken with that object in view, and two such appliances were now in Sheffield to be applied, he believed, in conjunction with annealing furnaces. He might call Sir Lowthian Bell's attention to the fact that in one particular case (as shown in the diagram) the temperature varied from 800° to 1650°. That was certainly a very great variation. There was not the slightest doubt that it was to the temperature of the effluent gases they must look for the most important indications as to the working of blast-furnaces. Very high testimony to the efficacy of the appliance was afforded by the following paragraph in the President's address:—"At the Dowlais Company's new works at Cardiff, Mr. Edward P. Martin has attained a production of upwards of 1400 tons per week, using the usual Rubio ore, and with rather less than 20 cwt. of coke per ton." He believed that result was obtained while the autographic recorder was attached to the furnace, and he hoped that its indications had been useful in enabling this output to be attained.

Mr. E. P. MARTIN said that was the case.

The PRESIDENT said he was sure the members would accord a hearty vote of thanks to Professor Roberts-Austen for his interesting paper.

CORRESPONDENCE.

Mr. C. LOWTHIAN BELL, referring to the curves he published in the Proceedings of the Cleveland Institution of Engineers, stated that it frequently happened that the remark B.L. (bell lowered) was placed on the diagrams some time before the fall in temperature was apparent. That, of course, was not the case. The temperature *fell* immediately the cold material was put into the furnace, or, in other words, as soon as it passed or was falling through the gases. As soon as the bell was lowered, the

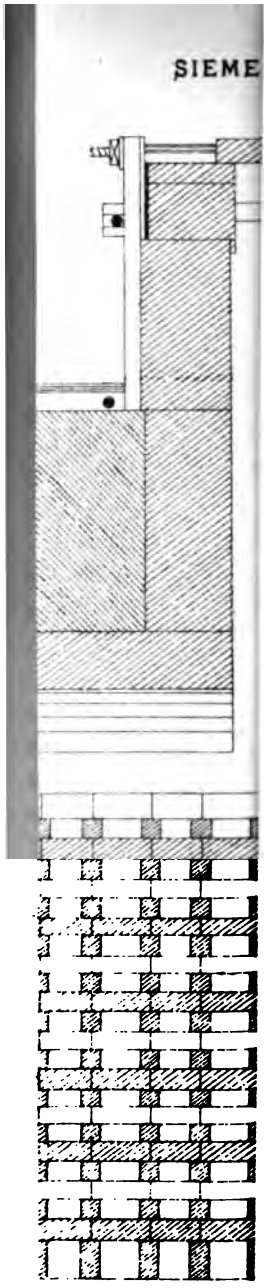
materials fell through the gas, and being cold, cooled it. In his diagram referred to by the Professor, the discrepancy could be accounted for in two ways:—(1.) An observation was taken at say 2 hours 55 minutes, and another at 2 hours 56 minutes, the bell being lowered at 2 hours 57 minutes. Had a continuous recorder been employed, the curve would have risen from 2 hours 55 minutes until 2 hours 57 minutes, and then fell, though not, he thought, in a straight line. At 2 hours 57½ minutes the gas passed through material falling into the furnace. At 2 hours 58 minutes the added material rested on top of the material in the furnace. At 2 hours 58½ minutes the conditions were the same. After that there was a reduction of temperature, the temperature decreasing with the increase of heat of the material, until at 3 hours the gas began to rise in temperature. (2.) The second explanation of the discrepancy was, that if he had had a recording instrument, the person taking the time at which the bell was lowered might have taken the time at which it was closed again.

At Skinningrove Ironworks a blast and charging recorder was in use. The record removed from the drum showed punctures made by the lever of the bell completing an electric circle whenever the bell was lowered. That appliance possessed great advantages; the manager could see that his men had been working. If they had not, the excuse given probably would be that it was not necessary to lower the bell, as the furnace was hanging, and there was no room for any more material. In such case the recording pyrometer would be advantageous. If the furnace was hanging completely, no blast would be passing through, and no gas coming out. The temperature would consequently first rise by radiation from the sides of the down-comer, and then fall. If that did not take place, the furnace had not been hanging, and the assertion made by the furnaceman was not true. That proved that, although the Skinningrove plan was a good one, it was not perfect, and required the pyrometer as a check.

Mr. C. COCHRANE stated that, in reference to a falling in the temperature of gases in the down-comer of a blast-furnace when the bell was lowered, although it was explained that this could not arise from the admission of cold ore, he failed to see

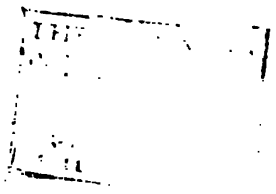
that a clear explanation of the phenomenon was given. directed attention to the circumstance that the escaping g their descent lost a portion of their sensible heat, so temperature of 600° at the top of the furnace might become 500° through the effects of radiation from the of the down-comer in the passage of the gases down. When the bell was lowered for charging materials, the ple gas in the throat of the furnace needed to force those onward to stoves and boilers ceased, and with the escape in atmosphere the gases became reversed in the down-come were now pressed upwards by the plenum in the gas ma flues below, thus allowing the cooled gases from below to a the pyrometer placed in their path.

The following paper was then read :—



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NOTES ON PUDDLING IRON.

By JOHN HEAD, F.G.S., M. Inst. C.E.

In the year 1868 the late Sir William Siemens read a paper before the British Association on puddling iron, which formed an epoch in the history of the literature of that process. In that paper the theory was advanced that the oxidation of carbon, silicon, and other substances to be removed from pig iron during puddling could be entirely effected by means of oxygen obtained from the fettling used for lining the pan, or by means of that obtained from hammer-scale, or other iron oxide thrown in expressly with the charge.

The theory enunciated by Sir William Siemens was supported by sound argument, and by an experiment made in an open-hearth steel-melting furnace at Birmingham, and has been generally accepted by various authors who have since written on the subject of puddling.

There can be no question that this theory can be realised in practice in a puddling furnace, provided that the pig iron used does not contain an excess of silicon, or that time can be allowed and a low furnace temperature ensured for its elimination. By Table I. which follows, it is seen that the experiment made by Sir William Siemens in the open-hearth regenerative gas furnace, mentioned in his paper referred to, required six hours for its accomplishment. The pig iron was melted and purified upon a sand bed, and under a protecting covering of glass.

Table I.

Description.	Time.	C. Per Cent.	Si. Per Cent.	
Acadian pig iron	...	4·0	1·50	
Sample No. 1	After one hour.	0·6 comb. / 2·3 graph.	2·9	1·08
Sample No. 2	After two hours.	2·4	0·96	
Iron ore added Sample No. 3	After three hours.	2·4	0·76	
Iron ore added Sample No. 4	After six hours.	0·25	0·046	

Sir William Siemens would have argued, had the question been raised, that molten pig iron on the bed of his open-hearth steel-melting furnace under a protecting covering of glass, was in a very different condition to molten pig iron in a puddling furnace, in intimate contact with iron oxides, and that the elimination of impurities would be much more rapid under these conditions than under those selected for the experiment which he desired to make. That experiment was intended to prove, and did prove, that carbon and silicon can be eliminated from molten pig iron without flame or air coming in contact with the metal under treatment.

Many regenerative gas puddling furnaces were set to work for puddling iron, which were constructed to carry out the process in accordance with this theory; and at some works, notably at those of Messrs. Nettlefolds, of Wellington, Shropshire, these furnaces gave every satisfaction. Messrs. Nettlefolds built about thirty of these puddling furnaces, and continued to use them until they removed their works to Newport, Monmouthshire, when they abandoned the use of iron, and adopted steel as a material for the manufacture of their high-class products. The same kind of furnace was also built at other works; but in some cases it was noticed that difficulties were experienced, which induced Sir William Siemens to make alterations in the flame-ports of his furnace.

The construction of flame-ports shown in the accompanying figure (Plate VIII.) was that adopted by him in 1871 for the puddling furnaces erected at the works of Messrs. Langlois & Co., Basse-Indre (France), and elsewhere. This form of flame-port was not adopted in the first instance, but in consequence of the complaints referred to. It will be seen that in this form a certain amount of contact between the flame and the iron to be puddled is secured; and it is noteworthy that with the adoption of this modification all complaints ceased.

Sir William Siemens would no doubt have observed that this alteration in the flame-ports of his furnace involved a departure from the theory enunciated in his paper read before the British Association a few years previously. When he made that alteration, however, he was fully engaged in perfecting the details of manufacture of the Siemens steel process; he was thus prevented

from following up the puddling process with the energy and thoroughness which he displayed in his early experiments, which experiments, carried out on a scientific basis, under his direction, would undoubtedly have led to most valuable results if they could have been continued. Owing to the circumstance that chemists are not usually employed at ironworks, analyses of the iron puddled, and of the puddled bar produced, were not supplied; but it is thought that the reason alterations were required in the puddling furnaces erected at some works was due to the circumstance that the pig iron treated at those works contained a larger amount of silicon than that at other works.

There are not many analyses of the various brands of pig iron used for puddling, and of the puddled bar produced therefrom, to be found in the numerous metallurgical books and papers which have been consulted; and Tables II., III., IV., and V. contain the only analyses of this kind that have been found.

TABLE II.

Analyses of Puddled Iron, at different Stages of the Operation, made by Messrs. Crace Calvert and Richard Johnson of Manchester (*Phil. Mag.*, September 1857).

Description.	Time.	C.	Si.	S.	P.
	O'clock.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Cold blast Staffordshire— No. 3 grey, charged . .	12·00	2·275	2·720	0·301	0·645
Sample No. 1 . . .	12·40	2·726	0·915	...	...
„ „ 2 . . .	1·00	2·905	0·197	...	...
„ „ 3 . . .	1·05	2·444	0·194	...	...
„ „ 4 . . .	1·20	2·305	0·182	...	. .
„ „ 5 . . .	1·35	1·647	0·183	...	...
„ „ 6 . . .	1·40	1·206	0·163	...	...
„ „ 7 . . .	1·45	0·963	0·163	...	...
„ „ 8 . . .	1·50	0·772	0·168	...	...
Puddled bar „ 9 . . .	...	0·296	0·120	0·134	0·139

Table III.

The following analyses by Mr. Louis illustrate the changes produced during the puddling by hand of Nova Scotia pig iron (*Ency. Brit.*, Art. *Iron*, p. 325):—

Description.	C.	Si.	P.	Mn.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Pig iron in fusion . . .	2·36	1·11	0·36	0·78
8 minutes after fusion . .	1·89	0·14	0·25	trace
13 ,, ,, ,, . .	1·75	...	0·26	0·09
18 ,, ,, ,, . .	1·57	...	0·23	trace
22 ,, ,, ,, . .	1·10	...	0·23	trace
40 ,, ,, ,, . .	0·16	...	0·09	0·07

Table IV.

Analyses of English iron, made for Sir William Siemens, and published in his paper on "Puddling" of 1868:—

Description.	Si.	S.	P.
	Per Cent.	Per Cent.	Per Cent.
Pig metal	1·97	0·08	1·160
Puddled bar	0·20	0·017	0·237

Table V.

In Sir Lowthian Bell's work on the Manufacture of Iron and Steel, London, 1884, Section "Puddling," &c., the following analyses of Bowling iron are found:—

Description.	C.	Si.	S.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Cold blast pig	3·656	1·255	0·033	0·565
Refined metal	3·342	0·130	0·025	0·490
Malleable iron produced from refined metal	0·226	0·109	0·012	0·064

Table VI.

The following analyses of iron have been kindly furnished by the Lilleshall Company :—

Description.	Si.	S.	P.	Mn.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Lilleshall hot blast pig No. 3 .	1·050	0·048	0·58	1·14
Puddled bar from do. . .	0·161	0·016	0·18	0·07

Table VII.

The following analyses are extracted from a great number of analyses of ironstone, limestone, coal, pig, and finished iron which have been obligingly placed at my disposal by Mr. F. T. Woodcock, who was associated in making these analyses, and sometimes made them entirely himself. They refer to iron made at the Ebbw Vale Company's Cwmbran works in 1858 :—

Description.	Si.	S. and P.	C.
	Per Cent.	Per Cent.	Per Cent.
Pig iron	1·23	0·370	2·57
After one hour	0·41	...	...
After two hours	0·07	...	...
Finished bar	0·05	0·023	0·315

The following analyses of malleable iron alone have been found in the works mentioned against each set.

Table VIII.

In Sir Lowthian Bell's work already referred to :—

Description.	C.	Si.	S.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Bowling 1¼ square bar . .	0·015	0·157	0·005	0·220
Lowmoor rivet iron . . .	0·200	not given	trace	0·115
Monkbridge best plate puddled by hand	0·018	0·151	0·004	0·097

Table IX.

In Muspratt's Chemistry, p. 435 :—

Description.	C.	Si.	S.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
German strong iron . . .	0·40	0·01	trace	...
Do. weak	0·09	0·03	trace	...
Welsh puddled iron . . .	0·41	0·08	trace	0·40

Table X.

In T. Bayley's "Assay and Analysis of Iron and Steel," 1884 :—

Description.	Combined C.	Si.	S.	P.	Mn.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
New British Iron Co.'s "Lion" brand (ordinary)	0·21	0·13	trace	0·13	nil

Table XI.

In Greenwood's "Iron and Steel," 1884 :—

Description.	C.	Si.	S.	P.	Mn.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
K. B. W. best bar iron . .	trace	0·170	0·028	0·200	0·140
Swedish O O	0·075	0·114	0·032	0·004	trace
Lowmoor armour plate . .	0·016	0·122	0·104	0·106	0·280
Round bar W R 3 . . .	0·180	0·019	0·014	0·074	trace
Armour plate	0·230	0·014	0·190	0·020	0·110

Table XII.

In Vosmaer's work entitled "The Mechanical and other Properties of Iron and Steel," 1891 :—

Description.	C.	Si.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Swedish puddled iron . . .	0·07	0·10	0·02	...
Yorkshire puddled iron, best .	0·07	0·06	0·09	...
Yorkshire puddled iron, best .	0·15	0·21	0·12	...
Staffordshire puddled iron, best .	0·06	0·20	0·25	0·02
Surahamman puddled . . .	0·05	0·08	0·02	...

Mr. Vosmaer remarks that for puddling, silicon should not exceed 1 per cent. in the pig iron.

In the works consulted several analyses of iron made in rotary puddling furnaces are to be found, and also analyses to illustrate the gradual purification of iron which takes place in those furnaces; but these analyses are not quoted, as rotary furnaces, although much experimented on, have not come into general use.

From the analyses quoted it is seen that the puddling operation should be effected in less than two hours' time with practically complete elimination of silicon. According to Messrs. Crace Calvert and Johnson's analyses the silicon in the pig iron puddled was 2·72 per cent. This is a high figure, and it will be noticed that 1·8 per cent., or two-thirds of the amount of silicon it contained, had disappeared forty minutes after the iron was charged into the furnace. At this time the iron was probably entirely melted, and twenty minutes later the silicon was further reduced by 0·718 per cent., equal to an additional reduction of one-fourth of the original amount. Subsequently the silicon in the metal was only reduced by 0·077 per cent. in the whole course of the puddling operation; the proportion remained practically stationary for fifty minutes, and 0·048 per cent. of silicon appears to have been eliminated during balling. From this circumstance it is clearly seen, as is well known, that when a certain temperature is attained in the puddling furnace the elimination of silicon ceases. According to Mr. Louis's analyses, the Canadian pig iron, which he was dealing with, contained only 1·11 per cent. of silicon when fused, and the whole of this amount had disappeared when the iron had attained the boiling point, or, in other words, by the time the highest furnace temperature had been reached. The proportion of silicon contained in the Canadian pig iron experimented on by Mr. Louis thus seems to have been extremely low, and if so, such pig iron might, I think, very well be puddled in the Siemens furnace by relying entirely on the oxygen contained in the fettling.

The mixture of pig iron used at Messrs. Nettlefolds' works at Wellington may also have contained only a slight amount of silicon, although the absence of analyses prevents an absolute assertion upon this interesting point being made. At the other works where the Siemens furnaces were erected, and complaints arose, in the first instance, it is thought the pig iron used contained a large proportion of silicon; hence the necessity of having recourse to a slight

modification of the flame-ports of the regenerative gas furnace, so as to obtain some oxidation of the metal by the flame. This is shown by the following analyses of the pig iron used and the puddled bar produced at a works in England, where ordinary iron is being made:—

TABLE XIII.

Description.	Si.	S.
	Per Cent.	Per Cent.
Pig iron (average of several analyses) . .	1·65	0·131
Puddled bar, bad	0·362	0·050
Puddled bar, good	0·282 0·250	0·0315

It will be noticed that the chief difference between the bad and the good quality of iron produced consists in the elimination of a little more silicon in the latter case, and the flame-ports of the furnace were altered so as to obtain that result. A different arrangement of flame-ports, however, was adopted to that shown in the figure accompanying this paper, with a view of enabling the oxidising action to be effected either by burnt gases or unburnt air, or again by the admission of cold air upon the surface of the iron in fusion, and particularly to allow the furnace to be worked at will with an oxidising or a reducing flame, great importance being attached to the use of a reducing flame during the balling up of the iron.

The following is an average analysis of Spanish pig iron used for the production of high-quality iron, and analyses of the good and other finished bar iron made therefrom:—

TABLE XIV.

Description	Si.	S.	P.
	Per Cent.	Per Cent.	Per Cent.
Pig iron	1·680	0·105	0·050
Bar iron, bad	0·327 0·331	0·033	trace
Bar iron, good	0·103	0·032	trace

It will be noted that the only difference between one kind and the other is that the inferior is found to contain 0·329 per cent. of silicon, and the good to contain only 0·103 per cent.; in every other respect the analyses are identical.

In the presence of the favourable results obtained in working the new-form Siemens furnace for puddling, it will not be surprising that many new applications of these furnaces have been made in England and abroad. At a works near Sheffield, three double puddling furnaces are now working, as also three heating furnaces; the latter may also be called double furnaces, as each of them does double the amount of work done in the grate furnaces they have superseded.

The analysis of pig iron, or mixtures of pig iron, used for puddling, and of the puddled bar produced therefrom, are scantily dispersed through the literature relating to the puddling process; but it is considered that those given are sufficient to warrant the deductions arrived at. It is hoped that the reading of this paper may lead to an interesting discussion, and that iron-masters, who are also chemists, or have the advantage of having chemists at their works, will take up the subject from the point of view here indicated, and will furnish the Institute with records of their work in this direction.

My son, Mr. Archibald Head, made for me the set of analyses of English and Spanish iron quoted, in the Metallurgical Laboratory at King's College; this he was kindly allowed to do by Professor Huntington, to whom my thanks are due. My thanks are also due to my assistant, Mr. E. W. Harvey, who furnished me with a list of some of the authorities to be consulted, and with one of the analyses quoted, and to my friend, Mr. E. F. Bamber, for having made an exhaustive bibliographical search for me.

DISCUSSION.

Mr. G. J. SNELUS said he could not help thinking that Mr. Head would have done well to have referred to the results obtained in the rotary furnace, although, as he had said, that furnace had not come into general use. There was no doubt that the mechanical portions of those furnaces were defective. He had always hoped that they would be improved, but he thought a very good reason why they had not come to the front was that the necessity for them was entirely, or almost entirely, removed by the increased use of steel. At the same time he thought if Mr. Head would refer to the elaborate series of analyses that were made at the time of the investigation of the Danks process, he would find a great many points more fully elucidated than in the results which he had given in his paper, most of which were very ancient, and made before present methods of analysis were in use. The Danks process was capable of further improvement, but he ventured to say that when the experiments he referred to were made, more was known about the chemistry of iron and steel making than was known at the time when some of the early analyses quoted in the paper were made. At all events, the author would find the theory of puddling, as far as the chemistry of the process went, more fully elaborated in those results than in any of the results given in the paper, and he did not see why they could not have been used in discussing a question of that sort. He should like to point out that the elimination of the silicon, on which Mr. Head placed so much importance, commenced before the pig iron was actually molten. During the melting of pig iron in any process of puddling or steel-making, the silicon, and the phosphorus, were rapidly eliminated while the pig iron was in a pasty condition and gradually melted down. If reference was made to any analysis of metal from a puddling furnace or from an open-hearth furnace, it would be found that a great deal of oxidation was going on during the melting of the pig iron. He believed one reason why molten pig iron had not been used directly in the puddling furnace and in the open-hearth furnace more freely than it had been was

because the oxidation which went on during the melting down of the pig iron was so great that the process was facilitated. It went on much faster than it did when the pig iron was in a molten state and lying dead on the bath. He thought that was a point which was very often overlooked. In making his investigations of the Saniter process, he was very much struck with the amount of change which had gone on between the pig iron and the molten bath, and that was the one thing which struck him in investigating the Danks process. He well remembered going to his old professor, Dr. Percy, and pointing out to him the enormous change which took place between the pig iron and the metal bath owing to the oxidation going on, and to the reactions which went on during the mere process of melting down. That result would take place whether they were working in an open-hearth furnace or whether they were working in an ordinary puddling furnace.

Mr. H. LOUIS said he should like to make a few remarks with reference to the analyses which the author had quoted from his (Mr. Louis's) paper on puddling.* He had read that paper before the Institute fourteen or fifteen years ago, and he had not referred to it since, so that he was speaking more or less from memory. He could most distinctly corroborate what Mr. Snelus had said with regard to the desiliconising of pig iron before the melting was completed. If he remembered rightly, the pig iron which he had employed contained something over 2 per cent. of silicon. What happened during the course of the melting was this: the pig iron was charged cold on the bed of the puddling furnace, the puddler put on a good fire, and as soon as the iron began to get red-hot he turned it, and when it got close on the melting-point he broke it, and then left it alone until the melting down had taken place. During that time a skin of oxide of iron formed on the surface of the pig iron, and if the silicon were to be eliminated by the action of the air only, it was obvious that the amount of silicon taken out would be very small indeed, seeing that each pig was broken into four pieces only, so that the surface of the pig iron exposed, compared with its total bulk, was very small; therefore if the silicon were to be removed by the

* *Journal of the Iron and Steel Institute*, 1879, p. 219.

action of the atmosphere or the furnace gases, there would be very little silicon indeed eliminated. What he contended was that a skin of oxide of iron formed over the entire surface of the pig iron exposed to the oxidising action of the furnace gases. Whilst the melting took place, a mixture of the molten metallic iron with the fusible oxide of iron took place, and during that time there was a very violent interaction. Perhaps he did not make himself quite clear as to the period when the desiliconising occurred. It was during the time the pig iron was being melted down together with the oxide of iron that the principal elimination of the silicon took place. He was thoroughly convinced from the result of his puddling experiments that quite 50 per cent. of the silicon originally present was in ordinary cases taken out before the pig iron was completely melted, so that the bath of molten pig iron contained about 50 per cent. of the silicon present in the original pieces of pig. As a semi-proof of what he said, he might point out that as soon as the pig iron was once melted down, they never saw molten pig iron again in the puddling furnace, unless exposed accidentally by a chance stroke of the rabble. The moment the pig iron was melted down, a layer of cinder, mainly silicate of iron, was formed on the surface of the pig iron, completely covering it. That cinder was of course largely derived from the siliceous ingredients of the furnace bottom and fettling, and from sand adhering to the pig iron, but there was also a considerable proportion from the silicate of iron produced by the chemical reaction he had described.

He had also noticed that the author did not give effect to what he himself thought was a very important matter in puddling, namely, the chemical effect of the mechanical action of the puddler's work. In order to get a fair notion of that, he had himself worked as under-hand to a puddler for six months. He was then able to make a fairly satisfactory heat of iron; and it was only when he understood the process from a practical point of view that he commenced his experiments. He came to the conclusion that the mechanical action of the puddler's rabble brought with it a great deal of chemical action. That was, he thought, one great reason why those mechanical revolving furnaces were never so successful as they were expected to be. As an example of his meaning: when the puddler found his iron a

little sluggish, he lifted the rabble right off the foreplate, bore on the end of it with all his weight, and rubbed it up and down the bed of the furnace. The result was that he detached and scraped off a portion of the fettling of the furnace, and of the highly oxidised pasty matter which composed the bed of the furnace, and as he scraped it off, he by that means mixed it with the iron, and so promoted the oxidation of the carbon, phosphorus, &c., which he wanted to produce. He had no doubt that the varying mechanical action, and the way in which the puddler scraped round the corners of the furnace, and mixed the materials in it, had a great deal to do with promoting and completing the chemical action that took place. He did not wish to be understood as recommending all such practices as the one described by him; he merely wished to point out how the intelligent use of the rabble affected the chemical reactions in the puddling furnace. Finally, there was another point on which he should like to record his opinion, viz., tables 13 and 14, in which the author gave analyses of puddled bar containing over one-third per cent. of silicon. He did not believe that any puddle bar, even bad puddle bar, ever contained anything like that amount. He should like to have some explanation on this point, but his own impression was that the silicon recorded in the tables could not possibly have been silicon in the bar, but was derived from silica mechanically intermixed with the iron in the form of slag, which had not been determined separately by the analyst.

Mr. JEREMIAH HEAD said that the writer of the paper lamented that he had not been able to find any systematic or scientific record of experiments on what went on in the puddling furnace. He did not seem to know or to remember that a few years ago a very careful series of experiments were made at the Königshütte Ironworks in Upper Silesia. The author of these experiments divided the process of puddling into periods of something like five minutes each, and took samples from the hearth at each of those periods. The samples were analysed by Dr. Kollmann of Oberhausen, and the results were given in tabulated form. He (Mr. Head) was so much struck with them as the best series of experiments on puddling that he had seen, that he arranged them into the form of a series of curves, and exhibited and explained

them in a small diagram at the meeting of the Institution of Mechanical Engineers held at Birmingham on the 18th of July 1876.* He might say that those curves entirely confirmed what the speakers in that discussion had already stated, viz., that the bulk of the silicon disappeared in the melting. The sulphur, phosphorus, and manganese went rather quicker at first, but otherwise steadily from beginning to end. The carbon was the one element that held back, and even slightly increased until melting was complete, when it gradually disappeared. The curves produced were really very similar to some curves which the President himself exhibited at an Iron and Steel Institute meeting some years since, in his illustrations of what took place in the basic Bessemer converter. There was no doubt that one thing which made it difficult to determine the constituents of puddled iron was the fact that the impurities are mainly contained in the remnant of cinder mixed with the iron. It was therefore quite clear that the amount of the impurities depended largely on the mechanical processes of shingling and rolling, in removing more or less effectively the cinder from puddled bar or finished iron. Having had considerable and rather unfortunate experience in times past with rotary puddling with the appliance known as the Crampton furnace, he could confirm what Sir Lowthian Bell said as to the very great purity of the wrought iron produced in that way. There was no doubt whatever that it was much purer than was usually got by hand-puddling, and for some reason or other it was much more free from cinder, which might partly account for it. As conducted by that process, however, there was one great difficulty which must permanently have prevented success. It would be remembered that by the Crampton process the furnace was heated by coal-dust. However fine the coal-dust was ground, there was not sufficient time during its passage into and out of the furnace for the solid carbon to be consumed. The gaseous portion of the coal-dust was burnt at once, but a residue of solid coke was left in the form of dust which had not time to get burnt. That fine coke-dust got into the iron, was lapped up in it, and afterwards reappeared in the bar, or the plate, or the rail, or whatever it

* *Proceedings of the Institution of Mechanical Engineers*, 1876, p. 266, and plates 45 and 46.

might be. When the blooms were re-heated and passed through the rolls, those little pieces of coke-dust seemed to decompose any oxide of iron there might be in the cinder round about, and produced, he supposed, carbonic oxide, which made a blister; consequently the blooms, or the plates, or whatever they were, were always liable to be covered with blisters from those little bits of coke-dust. Of course the main and overwhelming cause which prevented the further consideration and development of rotary puddling was the advent of mild steel made by the Bessemer and open-hearth processes. The products of those systems were so manifestly superior to and cheaper than anything that was likely to be obtained by rotary puddling, that it was obviously useless to give any more attention to it. He hoped that if the author of that paper wanted to get a systematic knowledge of what occurred in the puddling process, he would consult the experiments to which he (Mr. Head) had referred.

Mr. Henry A. Webb said that he had had some experience in the working of gas-furnaces for puddling, and unfortunately his experience had not been satisfactory. As a rule, the working of gas-furnaces had not been found advantageous for puddling, although it had for heating. The reference in the paper to the works of Messrs. Nettlefold was so far unfortunate that their immediate successors in those works lost a large sum of money in working those furnaces.

The President asked if producer gas was used.

Mr. Webb said that it was. The point to which he wished to direct attention was with reference to the practical process of puddling. The action which was described by Mr. Louis as the scraping of the bottom of the puddling furnace, he thought, was only necessitated by the insufficient charging of oxidising material. If a better supply of oxidising material in the shape of fettling had been charged with the pig iron, it would not have been necessary to scrape the bottom of the furnace. With regard to the remarks of Mr. Snelus on the early action between the slag and the molten pig iron, the effect of it was to very much weaken the slag. The slag became so very siliceous that its action in

the later stages of the puddling was weakened. Although it had been shown that 50 per cent. of the silicon was removed almost immediately, he apprehended that the important part of the process was the later part, when it was desired to remove the last traces of the silicon. He should like to suggest to gentlemen connected with the puddling of iron the importance of considering the application of lime. Some years ago he puddled many thousands of tons of iron with a large proportion of lime in the fettling, with the most satisfactory results. He was quite aware that all the text-books told them that they could only produce a metal of no value by puddling with lime, and that the resulting iron was red-short and useless on account of the material being intermingled with slag. He could only say that, working the furnace at a very high temperature, he did not get those results. He got practically more iron than he put into the furnace, and it was extremely tough; and though it was made from a medium-class iron, he was able to apply it to purposes for which only high-class irons would otherwise have done. The only difficulty he had had was the mechanical one of getting rid of the slag; but after the light shed upon the matter by Mr. Saniter, he thought that possibly, by the use of chloride of calcium, he might have so thinned the cinder as to have had no difficulty. He felt sure that the puddling process could be very much improved and cheapened by the careful and intelligent use of lime in the fettling.

Mr. GEORGE ALLAN said he was very glad to see from the paper that the merits of the puddling furnace were not being overlooked at the present time. No doubt since Sir Henry Bessemer and others had been producing steel on so gigantic a scale, and in the cheapest conceivable manner, puddling had more or less fallen behind, and certainly the investigation of the process of puddling had not received due attention. When he was associated with the Motherwell Ironworks of the Glasgow Iron Company thirty years ago, it was a favourite practice of the then mill-manager, Mr. Thomas Morton, to attempt to produce what was called "physicked" steel from puddling by a dose of chemicals. Some years ago he (Mr. Allan) was led to arrange for an experiment being made in the puddling

furnace, in order to ascertain what might be the practical effect of a dose of aluminium. He was the engineer who was applied to by the Cowles' Company of America to carry out their first production of aluminium for compliance with the patent laws in Europe, and having thus become practically conversant with the metal, he wrote to one of his friends in Glasgow, Mr. Grahame Thomson, to request that an experiment might be carried out in one of the puddling furnaces of the Glasgow Iron Company. The result of that experiment was so extraordinary, that he was only surprised to think that it had not become generally known and repeated long ere now. With a simple dose of aluminium, not exceeding 0·25 per cent., the puddled bar was raised from a tensional strength of about 18 tons per square inch to a tensional strength of about 32 tons. The puddling was accomplished in the ordinary time by the usual puddler, and with no directions whatever, beyond his friend Mr. Thomson standing over the furnace and recommending the dose to be applied at the proper stage. The puddled balls were taken out, and they shingled in a most remarkable manner. They were of a more homogeneous character than they would have been in the ordinary way, and the bars rolled well. Finally, a piece from the puddled bar was put in a lathe and turned. The sample was of the most silky, beautiful appearance, and had a tensional strength of about 32 tons.

The results given in Mr. Grahame Thomson's report on experiments made with the Cowles aluminium iron in the puddling furnace were as follows:—

1st. The ingot weighed 13 lbs. and contained 7·11 per cent of aluminium, so that to get an alloy containing 0·25 per cent., 373 lbs. of iron had to be used. This, of No. 4 forge pig, was carefully weighed and charged in the usual type of puddling furnace.

2nd. When the pig iron was nearly all melted, the ingot, which had been previously broken in two pieces, was thrown in. It melted and mixed with the iron, but it was observed that it was considerably more refractory than the pig iron.

3rd. Puddling then commenced in the usual manner, and nothing unusual took place until the heat was about ready for balling, and just leaving the liquid state. It was then observed

that a considerable swelling of the charge took place, the cinder running freely from the overflow; this, however, lasted only for a few minutes, and the puddler had no difficulty in finishing the work in the ordinary manner and usual time.

4th. Shingling and rolling into puddled bar followed in the same way as common iron, the only difference observed being a decidedly harder feeling under the hammer and also in the forge mills.

The result of rolling from the puddled bars was extremely satisfactory.

In reply to a question by the President, Mr. Allan stated that no analysis was made. He thought, however, that the trial proved what might be done by further experiments in puddling. The method he had described would enable every ironmaster to convert his puddling furnace into a steel furnace without an enormous capital for expenditure in the way of plant. It was well worth the attention of the trade. One reason why it was not carried further at that time was undoubtedly the fact that aluminium was then still upon the descent from about 60s. per lb. to 20s. by the Cowles process, and now by the same process it was about 2s. 6d., so that there was some ground for hope that the puddling furnace might yet result in something very practical in the way of steel-producing.

Mr. JOHN HEAD, in reply, said he was glad to think that his paper had given rise to a lively discussion, and had brought out several points which he thought had been somewhat overlooked by chemists and others, who had devoted their attention rather to steel-making than to iron-making. Certainly, when the literature relating to the manufacture of steel and iron was considered, that of iron-making was found to be very far behind that of steel-making, although the latter was the newer process. He had given quotations from the literature to which he had been able to refer, and these, he thought, bore out the theory which he had enunciated in the paper. He was not acquainted with the paper on puddling referred to by Mr. Jeremiah Head, and he hoped that it might afford information on some of the points raised in his paper and in its discussion. He had been advised to look up

the literature of the rotary puddling furnace; he had already done so, as mentioned in the paper, but when asked to design puddling furnaces, he was required to make them of the ordinary kind, and he had to meet the conditions of puddling in such furnaces, which were different to those met with in rotary furnaces.

Some of the speakers in the discussion laid stress on the circumstance that most of the silicon is eliminated from the pig iron whilst melting. This he admitted, and, in fact, called attention to this circumstance in his paper. When referring to Messrs. Crace Calvert and Richard Johnson's analyses, he quoted the silicon in the pig iron puddled as 2·72 per cent., and read from his paper: "This is a high figure, and it will be noticed that 1·8 per cent., or two-thirds of the amount of silicon it contained, had disappeared forty minutes after the iron was charged in the furnace. At this time the iron was probably entirely melted, and twenty minutes later the silicon was reduced by 0·718 per cent., equal to an additional reduction of one-fourth of the original amount."

The analyses of Messrs. Crace Calvert and Richard Johnson being taken from the *Philosophical Magazine* of September 1857, of course refer to grate-puddling furnaces. But when, some years afterwards, regenerative gas-furnaces were introduced for puddling iron, the quality of the iron made was not, in some instances, so satisfactory at first as when using grate-furnaces for puddling the same mixtures of pig iron. Both Sir William Siemens and himself had met with the same difficulty, and he should have liked very much to have had chemists at the works, so as to have ascertained the cause of the trouble. Unfortunately chemists were not found at most ironworks, and he was left to surmise that the trouble might be due to the circumstance that the Siemens furnace, as originally constructed, did not eliminate silicon so rapidly as the ordinary puddling furnace, owing to that furnace attaining more rapidly than grate-furnaces the temperature at which the elimination of silicon would cease. The flame ports were therefore altered, so as to obtain some oxidation in the metal under treatment, when all complaints as to the quality of the iron produced ceased.

From an engineering point of view, it was immaterial whether

the means of oxidation provided in the furnace acted directly upon the substances to be eliminated, or whether, as was maintained by most metallurgists, himself included, there was a double reaction in the puddling furnace, iron being first oxidised, and the oxide of iron thus produced reacting upon the silicon. All he wished to point out was the necessity, when the iron to be puddled contained a large proportion of silicon, of providing in the Siemens regenerative gas puddling furnace means for obtaining a certain amount of oxidation before the metal is entirely fused. This was effected by Sir William Siemens, by the means indicated in the figure attached to his paper, and it was effected by other means in the new-form Siemens furnace, with the object of also ensuring that the balling-up of the metal might be carried out under a reducing flame.

The PRESIDENT said he was sure the members would desire to accord a hearty vote of thanks to Mr. John Head for his paper, which had elicited such an interesting discussion.

CORRESPONDENCE.

Mr. H. G. GRAVES stated that the author did not appear to have searched very thoroughly the abstracts given at the end of each volume of the Journal of the Iron and Steel Institute, in which the salient features of a large number of papers on puddling were given. Included in these abstracts were complete analyses by Dr. T. Tscheuschner * of the materials from the ore through the pig iron to the puddled iron, and the piled, welded, and rolled bar. Amongst these the following occurred:—

	Phosphorus.			Silicon.		
	I.	II.	III.	I.	II.	III.
Pig iron	0·67	0·31	0·32	1·22	1·12	1·22
Puddled iron	0·15	0·12	0·12	0·25	0·28	0·20
Rolled iron	0·06	0·08	0·09	0·24	0·28	0·18

* 1886, No. I., p. 325.

Numerous analyses were also given by Mr. A. E. Tucker,* and since 1886 other notes are given by Messrs. Tucker,† Turner,‡ Ranstrom,§ and Jacobsson,‖ whilst before that date numerous references to the puddling process would be found in the general indexes.

The PRESIDENT then announced that the next two papers were "On the Determination of Chromium in Ferro-Chromium," by Mr. William Galbraith, and "On Methods of Determining Chromium, with Notes on the Distribution of Chromium in British Irons," by Mr. J. E. Stead. They would be submitted by title, and if any member desired to make any remarks upon them, and would send them to the Secretary, they would be published in the Journal of the Institute. It was proposed to leave over the last paper on the list, that by Mr. Kupelwieser on "The Manufacture of Basic Steel," until September, as the author was unable to be present, but he had promised to attend the next meeting.

* 1887, No. I., p. 412. † 1888, No. I., p. 323. ‡ 1891, No. I., p. 119; 1892, No. I., p. 414, and 1892, No. II., p. 519. § 1891, No. I., p. 376. ‖ *Ibid.*

ON THE DETERMINATION OF CHROMIUM IN FERRO-CHROMIUM.

By WM. GALBRAITH.

In Mr. Hadfield's paper on "Chromium Steel" read before this Institute in September last, he rightly, I believe, gives the credit of introducing that metal to Mr. Baur. This was done in England at the works of Messrs. John Brown & Co., Limited, about 1876. At that time there was considerable discussion as to whether there really was chromium present or not, and certainly the determination of 0·05 or 0·10 per cent. chromium in steel by any of the then known methods was not a very simple matter, and moreover was exceedingly tedious. To determine it accurately, I devised, and described in the *Chemical News* early in 1877, a method which served its purpose very well, and enabled the determination to be carried out with great speed and accuracy. As time went on, however, chromium irons were made much richer, and when the Tasmanian iron, with about 8 per cent. of chromium, appeared on the scene, it was thought very rich. To-day, however, chromium irons are made with as much as 60 per cent. chromium, an index of the progress which metallurgy is making. As the metal rose in chromium I found the process was not too satisfactory, and that for two reasons—first, because it became increasingly insoluble in the sulphuric acid; and, secondly, for reasons which I shall presently show.

The process, I may here say, was simply carried out by dissolving the steel or iron in dilute sulphuric acid, to which was then added sufficient potassium permanganate to oxidise all the iron and chromium. This was boiled until all the permanganate was destroyed and the solution filtered, and the chromium determined volumetrically by means of ferrous salts by well-known means. There has been a little difference of opinion as to its utility in the richer chromium irons, and Mr. Hadfield, in the discussion on his

r (see *Journal*, 1892, p. 172, No. II.), states that Professor ld objects to it as giving too low results; but in the cases red to I think the results ought to be quite correct. Mr. g, again, in a paper read before the Society of Chemical stry (see *Journal*, 1891, p. 340), states that he does not so much difficulty in dissolving the higher percentages, and there need be no fear of getting too low results. Others told me the same. Personally I have not had much exnce with it for some years, but I have always found diffi- in dissolving anything (*i.e.*, completely) above 10 per cent. mium, and have otherwise found it to give low results. n there was much chromium present, I was in the habit of lving some soft steel with it, so that I was practically dealing a poorer chromium iron, *i.e.*, I brought it down to about 5 ent., and found I got reliable results. If there was any inle, of course that was treated separately. On account of this rence of opinion I have investigated the matter further, either vise a method better adapted to the higher percentages, or the view of modifying my process to suit these cases.

r. Clark has published (see *Journal of Society of Chemical Iny*, June 1892) and described some processes, most of which I tried with results not too satisfactory. I may say that Dr. k is the author of the soda-magnesia process of determining mium in chrome ores, and he applies it to the case of mium irons. My experience is that it requires repeated ment to get the oxidation complete, and, moreover, the sample ires to be finer than you can always get it. He is evidently tisfied with it, however, as he describes other and alternative ods. It appears to me to be the best of those which he ribes, and it does give accurate results, if the sample is fine gh, as already stated. I believe an attempt was made about , by Dr. Clark and Mr. Esilman, to use permanganate of potash e analysis of chrome ores, but with unsatisfactory results.

test the permanganate method, I carried out the following riments:—

cubic centimetres of a standard solution of potassium bichro- (1 cc. = 0·01 grms. Fe) was reduced with sulphurous acid, 10 cubic centimetres sulphuric acid added, and then boiled.

To this was added 5 grammes potassium permanganate, and the solution was again boiled till the permanganate was destroyed (i.e. for about ten minutes). This was filtered and washed, and to the yellow filtrate was added 5 grms. ammonia-ferrous sulphate (containing 13·95 per cent. Fe), and the unoxidised iron was determined with the same bichromate solution. This took 30·3 cc., showing a loss of 10·55 cc., thus—

$$13{\cdot}95 \times 5 = 69{\cdot}75 - 50 = 19{\cdot}75$$
$$30{\cdot}30 \text{ cc.} - 19{\cdot}75 = 10{\cdot}55 \text{ cc.}$$

The experiment was repeated, but this time the chromic acid was not reduced with the sulphurous acid.

The number of cubic centimetres taken were 29·80, showing a loss of 10·05 cc.—

$$29{\cdot}80 - 19{\cdot}75 = 10{\cdot}05 \text{ cc.}$$

Now this shows that the error is not due to non-oxidation of chromium by the permanganate, and in order to ascertain where the loss took place, the following experiments were carried out:—

25 cc. of the bichromate solution, made up to 50 cc., was treated as before, but was not reduced with sulphurous acid.

3 grms. iron salt were taken, which consumed 20·30 cc.—

$$13{\cdot}95 \times 3 = 41{\cdot}85 - 25 = 16{\cdot}85$$
$$20{\cdot}30 - 16{\cdot}85 = 3{\cdot}45 \text{ loss.}$$

The precipitated oxide of manganese (or manganate of manganese) from this was washed off the filter and boiled in water, and again filtered and washed. The filtrate was treated for chromium as above, taking 1 grm. iron salt. The cubic centimetres taken were 11·70 :—

$$13{\cdot}95 - 11{\cdot}7 - 2{\cdot}25$$
$$3{\cdot}45 - 2{\cdot}25 = 1{\cdot}20 \text{ loss.}$$

The washings were never absolutely colourless.

The experiment was again repeated, but this time the bichromate was previously reduced.

With 3 grms. iron salt 20·7 cc. were taken—

$$13{\cdot}95 \times 3 = 41{\cdot}85 - 25 = 16{\cdot}85$$
$$20{\cdot}70 - 16{\cdot}85 = 3{\cdot}85 \text{ loss.}$$

The precipitate, on being treated with water as above, took 11 cc.—

$$13{\cdot}95 - 11 = 2{\cdot}95. \qquad 3{\cdot}85 - 2{\cdot}95 = 0{\cdot}90 \text{ loss.}$$

Instead of using a bichromate of potash solution, I used a solution of chromic acid, 16·05 cc. of which oxidised 1 grm. of the iron salt (or 1 cc. = ·00807 Fe). 50 cc. of this was treated as before, being reduced with sulphurous acid.

With 4 grms. iron salt 15·9 cc. were taken—

$$16{\cdot}05 \times 4 = 64{\cdot}20 - 50 = 14{\cdot}20$$
$$15{\cdot}9 - 14{\cdot}20 = 1{\cdot}70 \text{ cc. loss.}$$

In another experiment the loss was 4·4 cc.

I now tried the effect of the presence of iron, and took 25 cc. chromic acid solution, 25 cc. water, and 10 cc. sulphuric acid, in which 1 grm. of wrought-iron drillings was dissolved, also 2 grms. of permanganate.

With 2 grms. iron salt 8·1 cc. chromic acid solution were taken—

$$16{\cdot}05 \times 2 = 32{\cdot}10 - 25 = 7{\cdot}1 \qquad 8{\cdot}1 - 7{\cdot}1 = 1{\cdot}00 \text{ loss.}$$

The precipitate was boiled in water and again treated with 1 grm. of iron salt as before.

With 1 grm. of iron salt 14·9 cc. of chromic acid were taken—

$$16{\cdot}05 - 14{\cdot}9 = 1{\cdot}05,$$

so that there was only a loss of ·05 cc.

On repeating this, 7·1 cc. were taken without retreating the precipitate, which, as will be seen, is quite correct, but on using 50 cc. chromic acid solution, the loss was equal to 1 cc., which was entirely recovered on treating the precipitate with water. These experiments, I think, show conclusively that in presence of an excess of iron, the process is accurate, and that the precautions I had taken were quite correct. Moreover, it explains why the results were low in rich chromium irons.

I need not explain or give details of the many methods I tried of getting all the chromium washed from the precipitate. Thinking probably that the filter was reducing or absorbing the chromic acid, I filtered through asbestos, but there was the same difficulty. I found, however, that if, when boiling with the permanganate and sulphuric acid, the boiling is prolonged for a few minutes till the precipitate is black, caustic soda did not dissolve any manganates from the precipitate (I presume the manganates are destroyed, and that the precipitate consists of oxide of manganese

only), and that the chromic acid was dissolved easily from the precipitate by its means.

The process thus becomes: Dissolve in sulphuric acid (1 in 6), add permanganate, and boil till precipitate is black; then dilute and make alkaline with caustic soda; filter wash, acidulate filtrate, and treat as before with the ferrous salt and potassium bichromate. As an illustrative test, I took 50 cc. potassium bichromate solution, with 10 cc. sulphuric acid, reduced with sulphurous acid, and proceeded as before, using caustic soda as described.

With 5 grms. of iron salt 19·7 cc. bichromate were taken—

$$13{\cdot}95 \times 5 = 69{\cdot}75 - 50 - 19{\cdot}75,$$

which is quite correct. This I verified repeatedly.

In its application, however, to chromium irons we have still to deal with what is left insoluble in sulphuric acid.

Dr. Clark mentions that A. Zeigler suggests fusing the chromium iron with caustic soda and nitrate of potash, and I have found this to be a very satisfactory method, one fusion of the insoluble being quite sufficient.

The best method of proceeding I find is as follows: Dissolve the chrome iron, as described, in sulphuric acid, and filter. The filtrate is treated with permanganate, as I have already described, and using soda.

The insoluble matter is dried and ignited in a porcelain crucible, then fused with say 6 grms. caustic soda and a little nitrate of potash in a platinum or silver crucible. It is fused perhaps for fifteen minutes, and is then dissolved in water, filtered and washed, and the filtrate made acid with hydrochloric acid, reduced with sulphurous acid, and the oxide of chromium precipitated with ammonia, filtered, dissolved in dilute sulphuric acid, and treated with permanganate like the original solution, or may be added to it.

In the case of a complete analysis, the fusion will be very useful, in which case you must fuse the original iron. It will be found, too, that the permanganate process is really the best way of dealing with the oxide of chromium precipitate. The old method is to weigh the precipitate as oxide of chromium, but this gives far too high results. Otherwise the oxide of chromium is not so easily dealt with as might be supposed.

In one sample I got results as follows :—

Using ·5 Grms.	Solution, with 7 Grms. Iron Salt.	Fused Insoluble, with 1 Grm. Iron Salt.	Chromium.
	cc.	cc.	Per Cent.
First experiment . . .	6·0	12·0	58·40
Second experiment . . .	5·7	11·90	58·63

In another sample, said to contain 28 per cent. of chromium, the results were—

Using ·5 Grms.	Solution, with 4 Grms. Iron Salt.	Fused Insoluble, with 1 Grm. Iron Salt.	Chromium.
	cc.	cc.	Per Cent.
First experiment . . .	15·6	11·40	26·67
Second experiment . . .	15·4	11·50	26·82

In another sample, said to contain 8 per cent. chromium, the results were as follows :—

5 grms. were treated as described, using soda; and with 2 grms. iron salt 12·7 cc. were consumed—

$$13·95 \times 2 = 27·90 - 12·7 = 15·20$$
$$15·2 \times 2 = 30·4 \times ·312 = 9·48 \text{ per cent. chromium.}$$

This was repeated, but without soda. With 2 grms. iron salt 15·4 cc. were taken—

$$27·90 \times 15·4 - 12·5 \times 2 = 25.00$$
$$25 \times ·312 = 7·8 \text{ per cent. chromium.}$$

The precipitated oxide of manganese was now washed from the filter and treated with soda and filtered, the chromium being determined in the filtrate. With 1 grm. iron salt 11·2 cc. were taken—

$$13·95 - 11·2 = 2·75 \times ·362 = ·858 \times 21·71$$
$$7·80 + 1·71 = 9·51 \text{ per cent. chromium.}$$

Another sample gave respectively—

50·58 – 50·63, and 50·63 per cent. chromium.

These samples were kindly given me by Messrs. Hadfield.

The amount of insoluble matter is not, of course, a matter of importance if it has to be fused at all, and will, of course, depend as much on the fineness of the sample as on the percentage of chromium.

For determining iron, &c., fusing with caustic soda and nitrate of potash is very convenient, and two fusions will usually be found sufficient when treating the iron itself.

I need not say that these figures do not represent all the work I have done on the matter; they are typical, however, of a great deal of it, and show clearly the cause of the error in high or rich chromium irons, and also the ease with which the chromium can be separated from the precipitate by means of a soda solution. It has not, I may say, lengthened the process in any way, as the treatment with soda leaves the precipitate quite granular, and it filters much more rapidly than from the acid solution.

ON METHODS OF DETERMINING CHROMIUM,

WITH

NOTES ON THE DISTRIBUTION OF CHROMIUM IN BRITISH IRONS.

By J. E. STEAD.

In these days when manual labour is so largely being replaced by machinery, and when the processes of production of iron and steel are so rapid, it is imperative that, in order to be of the greatest use, the metallurgical chemist in the laboratories of our iron and steel works must improve his analytical methods, and endeavour to obtain strictly accurate results in the very shortest period of time.

In days of old, in the beginning, when analyses were not in great demand, it was thought not at all bad work if a complete analysis of steel was finished in a week; now the work is done in a single day; and I am confident of this, that the analyses made to-day are of greater accuracy, and therefore greater value, than those made thirty years ago by the laborious and tedious methods then in use.

The methods used for the determination of chromium at that time were essentially gravimetric, and it took several days to make a single estimation.

In 1871, Dr. Clark of Glasgow published a new method for the volumetric determination of chromium in chrome ores,* by which means the amount of chrome was ascertained in a few hours.

At that time chrome steels and irons were not in use, and the method of Dr. Clark was not applied or applicable to the analysis of such material; but quite recently that gentleman has published a method specially adapted to the use of the iron and steel manufacturer.†

* *Chemical News*, vol. xxiv. pp. 286-304.

† *Journal of Society of Chemical Industry*, vol. xi. p. 501.

For details of the process reference must be made to the original article.

In brief, however, the process depends on the conversion of the chrome steels or alloys into sulphides, by heating them in a porcelain tube in an atmosphere of carbon di-sulphide, and subsequently into oxide by calcination in a muffle in an atmosphere of air, after which they are ground to powder and mixed with four times their weight of a mixture of magnesia and sodium-hydrate (5 parts MgO and 3 parts NaHO), and the mixture is roasted for half an hour, by which treatment the greater part of the chromium is oxidised to chromic acid. This is washed out with water, and the insoluble residue is again ground to powder and re-roasted, with an additional quantity of the magnesia mixture, and the calcined frit is again washed with water.

The mixing, calcination, and washing is repeated a third time, to ensure the complete separation of the last traces of chrome.

The combined filtrates now contain the whole of the chromium in the state of chromic acid, and possibly some manganese as manganate of soda.

To separate the manganese, Dr. Clark boils with peroxide of hydrogen, which precipitates it as peroxide.

By filtration, a clear filtrate, containing no oxidising substance other than chromic acid, is obtained.

Sulphuric acid and a known quantity in excess of a ferrous salt is now added.

The amount of iron not oxidised by the chromic acid is determined by a standard solution of bichromate of potash, and the iron oxidised by the chrome is in this way obtained, which, multiplied by 0·3119, gives the amount of chromium in the quantity of the material operated upon.

The accuracy of this method no one need question; but judged from a works analyst's point of view, it is a little tedious, and commands rather more time and attention than he could wish.

Galbraith's Method.

The next method of importance is that of Mr. William Galbraith,* described as follows:—

Method of Mr. William Galbraith on Analysis of Chrome Iron and Steel.

"Mr. W. Galbraith dissolves one gramme of the chrome iron in dilute sulphuric acid (about six parts of water to one of acid).

"Sufficient potassium permanganate to oxidise all the iron is now added, and then about as much more, and the solution boiled until the colour of the permanganate is destroyed.

"Potassium permanganate crystals are used, and it is necessary to have an excess of permanganate, otherwise some of the chromium may escape oxidation, especially if there is much chromium.

"The black or dark brown precipitate, consisting probably of a mixture of manganese, permanganate and oxide, is now filtered, washed well with hot water, and to the filtrate, which should, of course, be of a bright yellow colour, is added a known weight of ferrous sulphate, or preferably ammonio-ferrous sulphate, and the excess of iron estimated with a standard solution of potassium bichromate.

"This method gives very accurate results, and as it does not occupy much time (not more than half an hour), it leaves little to be desired.

"Steels are estimated in precisely the same manner, with the exception that two or three grammes of the sample are taken instead of one gramme."

According to this, nothing better, so far as accuracy and rapidity are concerned, could be thought of or devised than this process, and there is no doubt that in many steel works and other laboratories it has been and is extensively used.

The questions which at once present themselves are:—

1. Does the dilute sulphuric acid (one of acid to six of water) render all the chromium soluble?

2. Is all the chromium converted into chromic acid on boiling

* "Crooke's Select Methods of Chemical Analysis," p. 226.

with permanganate of potash when the method is worked in the manner described?

To answer the first question two samples of steel, one containing about 1·5 per cent. chromium, and the other about 5·5 per cent. chromium, were digested with dilute sulphuric acid, and when all action had terminated, the small amounts of black residue were filtered off and thoroughly washed, and after burning off the papers in a muffle, they were examined for chromium with the following results:—

Chrome in steel . .	1·5 per cent.	0·040 per cent. in residue.
,, ,, . .	5·5 per cent.	0·152 per cent. ,,

The next question which arose was, whether or not this residue is made soluble on boiling it with permanganate. In order to settle this point, after dissolving the steels in sulphuric acid, the process was carried forward to the second stage, but instead of filtering off the peroxide of manganese, it was removed by the addition of an excess of sulphurous acid, after which any unaltered residue was filtered off and examined as before.

This time no chromium was found insoluble in the first steel, and only 0·016 per cent. in the second.

It would appear, therefore, that in steels containing little chromium, sulphuric acid jointly with permanganate of potash effects complete solution, but that with alloys a little chrome still escapes.

As chrome steels rarely contain more than 1·5 per cent. chromium —the amount usually present being, as a rule, much less than that quantity—we may assume that in testing such material by this method in the past none has escaped solution.

As rich ferro-chromes are exceedingly difficult, if not impossible, to dissolve in acid, the Galbraith method is therefore inapplicable for the analysis of such material.

The question as to whether all the soluble chrome is oxidised by permanganate was answered by the following experimental results.

To several portions of pure ferrous sulphate, containing 2 grammes of iron, was added various quantities of chromium in bichromate of potash.

These mixtures were acidulated strongly with sulphuric acid, and were treated as directed by Mr. Galbraith.

No.	Chromium.		
	Added.	Found.	Loss.
	Grams.	Grams.	Per Cent.
1 . .	0·128	0·122	4·00
2 . .	0·064	0·0601	6·00
3 . .	0·064	0·0608	5·00
4 . .	0·144	0·1398	2·88
5 . .	0·128	0·1235	3·50

In all these trials no particular notice was taken of the amount of permanganate of potash used; care was, however, taken to have excess, but in no case was the quantity so large as recommended by Mr. Galbraith, and judging from the great difficulty of decomposing such an excess, I do not think it possible that the term "as much again" really was intended to be applied in all cases.

In order to ascertain the result obtained on using varying increasing quantities of permanganate of potash, all other conditions remaining constant, the following experiments were tried.

Three portions consisting of 10 grammes ferrous sulphate, 0·1664 grammes chromium in solution, 10 cc. strong sulphuric acid, and 300 cc. of water, were treated first with permanganate sufficient to oxidise the iron to peroxide, and then after boiling with 0·4 grammes, 0·6 grammes, and 1·2 grammes respectively of permanganate.

Boiling was continued for one hour, and the results obtained were as follows, viz. :—

Description.	Chromium.		
	Added.	Found.	Loss.
	Grams.	Grams.	Per Cent.
With 0·4 permanganate . . .	0·1664	0·1616	2·3
,, 0·6 ,, . . .	0·1664	0·1596	4·1
,, 1·2 ,, . . .	0·1664	0·1348	19·1

These results clearly show that the amount of permanganate requires to be carefully regulated, and that the smaller the

quantity added in excess, the greater the amount of chromic acid which will be obtained in solution.

It is probable that the peroxide of manganese in precipitating carries down with it a portion of the chromium which thus escapes detection.

As to what really does occur, has not yet been investigated.

It would appear, then, that when all known precautions are taken, the Galbraith process yields about 97·7 per cent. of the total chromium.

Mr. Galbraith may work his process in such a way as to obtain the whole of it. I cannot, however, obtain more.

In testing steels containing 1 per cent. of chromium, the loss of 2·3 per cent. is equal to 0·023 per cent., and the chromium found equal to 0·977 per cent.

In steels containing 5·50 per cent., a loss of 2·3 per cent. would reduce the chromium found to 5·37 per cent.

A New Modification of the Acid Permanganate Process.

After studying and working with Galbraith's process, a successful attempt was made to destroy or remove the insoluble peroxide so as to avoid filtration, and thus to simplify the determination.

Hydrochloric acid when of great strength acts upon chromates, chromous salts and free chlorine resulting; but it was found that a dilute solution of acid in water may be boiled with chromates without change, and that such acid will, on boiling, completely destroy or dissolve peroxide of manganese before attacking the chromates, chloride of manganese and free chlorine resulting, and that the whole of the chlorine, by energetic boiling, can be rapidly removed from the solution.

The same solution of hydrochloric acid also rapidly destroys permanganate of potash.

Based on these facts a modified permanganate process has been worked out in my laboratory.

In the first instance, if the amount of chrome is high after solution of the steel in sulphuric acid, the residue is filtered off and washed, the clear filtrate is boiled, and to the boiling solution (which should measure about 300 cc.) is added a saturated solution

of permanganate in water, in such quantity as to produce a strong pink colour, which does not disappear after boiling for 10 minutes.

40 cc. of strong hydrochloric acid, mixed with 40 cc. of water, are now added, and the solution is boiled briskly till the liquid is just clear; then 150 cc. of boiling water are added, and the boiling is continued till about 100 cc. of water have evaporated, when the solution remaining will be quite free from chlorine.

A sufficient amount of ferrous sulphate solution of known strength is now added, and the iron which remains unoxidised determined by a standard solution of bichromate of potash.

The iron, so ascertained to be oxidised by the chromic acid, is calculated into chromium.

The residue insoluble in sulphuric acid is burnt off and mixed with about 0·5 grms. of what may be called the tribasic reagent, consisting of:—

Pure lime or magnesia	200 parts.
Potassium carbonate	50 ,,
Sodium carbonate	50 ,,

and is heated at a bright red heat in a muffle furnace during the time that the soluble part is being prepared.

After heating for half an hour it is withdrawn, and the mass is dissolved in dilute hydrochloric acid, and the chrome determined with standard solutions of ferrous sulphate and bichromate of potash.

Working on known quantities of chrome in ferrous sulphate solutions, this method gave the following results:—

	Added.	Found.
No. 1 . . .	0·0032	0·0032
No. 2 . . .	0·1280	0·1282
No. 3 . . .	0·1600	0·1590

The following practical results, on testing a sample of chrome steel, will show exactly how the process is worked—

2 grms. of steel were dissolved in 30 cc. sulphuric acid (1 to 3).

The residue, after diluting the solution with 30 cc. boiling water and oxidising the iron with permanganate, was filtered off and washed with boiling water.

The filtrate was brought to boiling, diluted to 300 cc. with water, and 0·50 grms. permanganate of potash dissolved in boiling

water added, and, after boiling for ten minutes, 40 cc. of strong hydrochloric acid, mixed with 40 cc. of water, was poured into the solution, and the boiling continued till the brown peroxide had just disappeared; 150 cc. boiling water was then added, and the boiling continued till about 100 cc. of water had evaporated.

The solution was now free from chlorine.

50 cc. of ferrous sulphate, containing by titration with bichromate of potash 0·567 gramme of iron in the ferrous state, was now added to the solution, and the amount remaining unoxidised titrated with the following results, viz.—

Iron added	0·567 grammes.
Iron not oxidised	0·217 „
Iron oxidised by chromic acid . .	0·350
0·35 + 0·3119 + 50	5·458 per cent. chromium.

The residue prepared as before described oxidised 0·001 grms. of iron = 0·016 per cent. chromium.

	Per Cent.
Chrome in solution	5·458
Chrome in residue	0·016
Total percentage	5·474

The same steel tested by Galbraith's method, without filtering off the residue, gave 5·30 per cent., and 5·28 per cent. chromium.

We now pass on to consider another method, which is based on known facts in chemical science, and is a mixture of several methods rolled into one, and which may be called the

Hypo-Aceto Volumetric Method.

This method has been worked out in my laboratory, and depends on the fact that chromium oxide is totally precipitated as phosphate from iron solutions which contain sufficient phosphoric acid, when they are boiled with hyposulphite of soda, and after the excess of sulphur di-oxide has been boiled off with acetate of ammonia or soda.

The precipitate so formed is simply filtered off, slightly washed, and is afterwards dried and burnt off, pounded, mixed, and calcined with about ten times its weight of the tribasic reagent before described.

The heat best adapted for the calcination being a bright red, such as is obtained at the back of a Griffin's muffle furnace when the door is closed.

In from ten minutes to half an hour all the chromium will be converted into chromate.

The mixture is calcined in platinum capsules or crucibles, and no stirring or attention whatever is required, and the strongest heat may be applied directly.

The crucible is then removed, and when cold the mass will be found either slightly sintered together or as loose powder.

This mass is transferred to a beaker, dilute hydrochloric acid added, and the crucible is rinsed out into the beaker with a little more hydrochloric acid, and afterwards with water, care being taken not to have at any time more than one-fifth of the volume of strong acid.

Boiling water is now added to make a total volume of 200 cc., and the solution is boiled to free from any free chlorine which might possibly have been formed by decomposition of manganate.

The resulting solution is examined for chromic acid in the manner previously described, and the iron oxidised determined.

Instead of hydrochloric acid sulphuric acid may be used, but in that case the magnesia should be substituted for the calcic reagent.

When vanadium is present hydrochloric acid is inadmissible, for reasons presently to be explained.

This method, when applied to known quantities of chromium, gave the following results :—

No.	Chromium.	
	Added.	Found.
1	0·0032	0·0030
2	0·0320	0·0315
3	0·1280	0·1276
4	0·1600	0·1601
5	0·1600	0·1594

The slight loss shown above is probably due to a slight solubility of the phosphate of chromium in the boiling water used to wash it.

By using water containing 2 per cent. nitrate of ammonia to wash the precipitates instead of water, the following results were obtained :—

No.	Chromium.	
	Added.	Found.
1	0·0032	0·0032
2	0·0320	0·0321
3	0·0640	0·0641

The following directions for the working of this method when determining chromium in steel will make it clear.

Dissolve 2 grms. in either strong hydrochloric or dilute sulphuric acid, and, without filtering, nearly neutralise the free acid with caustic soda solution (1 to 50), boil the iron solution, which should have a volume of 300 cc., and add 10 cc. of phosphate of soda solution (1 to 20) and about one ounce of solid hyposulphite of soda, and continue to boil till free from sulphur di-oxide, then add 20 cc. of strong acetate of soda or ammonia and boil for five minutes longer, then filter off and wash on to the filter the precipitate with a boiling 2 per cent. solution of ammonium nitrate, and wash it four times with this solution.

Now dry it and burn off at a gentle red heat, when the residue will be left as a slightly coherent loose mass most readily reduced to exceedingly fine powder in a glass mortar.

This is ground up with ten times its weight (an excess makes no difference) of the tribasic reagent, and the mixture is returned again to the crucible and is calcined at bright redness for half an hour.

It is then removed cooled, dissolved in about 30 cc. hydrochloric acid and 150 cc. water; the liquid is then boiled for ten minutes, after which it is ready for titration.

The steel before referred to, by this method gave :—

	Chromium. Per Cent.
No. 1	5·474
No. 2	5·458
No. 3	5·464

The filtrate from the hypo and acetate precipitates were oxidised,

and the iron, together with any chromium which might have escaped precipitation, was thrown down with ammonia, and this, when dry, was ground up and heated with an excess of carbonate of soda and nitrate of potash, to render any chromium, if present, soluble.

When cold, the mass, on treating with boiling water, yielded a liquid quite free from chromic acid. We may assume, therefore, that all was precipitated in the first instance.

This method is most applicable when small quantities of chromium are present.

Where a good strong heat is not available, Dr. Clark's magnesia mixture should be used and the oxidation be effected in a porcelain crucible, care being taken not to heat too strongly, or the caustic soda will attack the crucible, and some of the chromium attach itself to the glaze and escape estimation.

Blair* advises, for the separation of chromium from iron, the use of barium carbonate, which must be applied to a cold ferrous chloride solution of the steel; but in following the instructions given and applying them to the analysis of the steel containing 5·46 per cent. chromium, only 3·63 per cent. was precipitated, although there was 2 grms. excess of carbonate used.

The filtrate from the precipitate was decidedly green.

When a neutral soluble phosphate was added to this solution, a precipitate of phosphate of chromium was at once thrown down, equal to 0·81 per cent. chromium, but the last portions of chromium were only removed by boiling the phosphatic filtrate with the carbonate.

I have found that on boiling phosphatic solutions containing chromium (in which all the iron is in the ferrous state) with either carbonate of magnesia or carbonate of lime, the chromium is precipitated as phosphate, and these agents may therefore be used instead of hyposulphites and acetates; but I prefer the latter, for the precipitated sulphur accompanying the phosphate of chromium leaves the precipitate after burning off the sulphur in a loose soft condition, which is readily crushed and most rapidly acted upon by the oxidising reagents.

* *Chemical Analysis of Iron*, pp. 181–183.

Chromium in Presence of Vanadium.

Vanadium is frequently present in pig iron, and such bein the case, careful trials were made to ascertain to what extent i presence would interfere with the determination of chromium.

The first question was, Are vanadium compounds carried dow with chromium phosphate when that substance is precipitate with ammonia, acetates, hyposulphates, &c.?

The following experiments were made to test this:—

Three portions of vanadous chloride, containing 0·0078 grms. vanadium, were mixed respectively with chromous solutions, eac containing 0·0199 grms. chromium.

A fourth portion of chromium solution was treated alone.

To each of the four solutions a little phosphate of soda wa added.

The simple chrome solution and one of the others were we boiled with a slight excess of ammonia, a third was boiled wit ammonia acetate, and the last with hyposulphite of soda.

The precipitates were well washed with a boiling solution 2 per cent. nitrate of ammonia, and after drying were burned o and weighed.

The weights obtained were as follows:—

Precipitant.	Chromium.	Vanadium.	Weight of Precipitant.
Ammonia	0·0199	none	0·0475
Do.	0·0199	0·0074	0·0580
Ammonium acetate . .	0·0199	0·0074	0·0595
Sodium hyposulphate . .	0·0199	0·0074	0·0600

This result clearly proves that when vanadium is present grav metric processes as usually conducted are useless, as it is show that an error of as much as 22 per cent. in excess may readily b made if no notice is taken of the disturbing element.

The precipitates obtained in the above trials were mixed wit about one gramme of the magnesia reagent, and were calcined at bright heat for one hour.

The frits were dissolved in sulphuric acid, and after adding known quantity of ferrous sulphate to each, what iron remain

unoxidised was determined with a standard solution of permanganate of potash added to the solution when it was quite cold (60°), and until a permanent pink colour remained, which did not disappear on standing for one minute.

The reason for using permanganate instead of bichromate is this, that whereas the latter has no effect on the lower oxide of vanadium when in solution, permanganate rapidly converts it into vanadic acid.

On calcining the mixed oxides in the muffle with alkaline bases they are converted into chromic and vanadic salts, and these are both reduced to lower oxides upon the addition of a ferrous salt, a portion of the iron of course being oxidised by the vanadic acid.

If, then, the iron remaining unoxidised is determined with bichromate, the iron found to be oxidised will represent the oxidation of both chromic and vanadic acid; and if the permanganate is used instead, it restores to the vanadous compound the oxygen it had given to the iron solution, converting it, in fact, into its original state of vanadic acid, and the iron oxidised by the chromium alone is in this way determined, and the chromium calculated as usual.

The precipitates treated in this way indicated the following amount of chromium :—

Weight of Precipitate.	Chromium.	
	Used.	Found.
0·0475	0·0199	0·01984
0·0580	0·0199	0·01984
0·0595	0·0199	0·01984
0·0600	0·0199	0·01984

It will be clear to all, from what has been said, that after titrating the solution with permanganate, the vanadium may be determined by a further addition of ferrous sulphate and the iron oxidised by the vanadic acid determined, and the vanadium found multiplying this by 0·914.

As an example of the simplicity and accuracy of this method, is based on the process given by Roscoe & Schorlemmer in

their treatise on "Chemistry," vol. ii. p. 287, and which has since been adopted by Lindemann* and C. H. Ridsdale† in their examinations of basic slag.

0·10 gramme of chromium in chromate of potash and 0·09776 gramme of vanadium in vanadic acid were mixed, acidulated with sulphuric acid, and both the chromium and vanadium were determined in less than three minutes, with the following results:—

Vanadium.		Chromium.	
Added.	Found.	Added.	Found.
0·0977	0·0976	0·100	0·100

If such a solution was to be assumed to be one entirely of chromium, and the titration made with bichromate, the calculation would have erroneously indicated the chromium as 0·13 instead of 0·100.

Both Dr. Clark and Mr. Galbraith advise the use of bichromate.

If they substitute permanganate instead, their methods will not be influenced by vanadium if it happens to be present.

When vanadium and chromium are present, as has been before pointed out, it is necessary to avoid the use of hydrochloric acid, for the permanganate of potash solution required for titrating the iron is unstable in the presence of such acid, and sulphuric acid must be substituted.

Ferro-Chromes.

When chrome alloys contain such a quantity of chromium as to make them difficult to dissolve in acid, they are, as a rule, hard and brittle enough to pound, and if they can be crushed to fine powder, they can be most readily oxidised by heating with the tribasic reagent before described, and that at one single operation.

This reagent, it will be noticed, is different from those used by Dr. Clark.

It was found in practice that the caustic soda, recommended

* *Chemical News*, January 5, 1883.

† *Journal of Chemical Industry*, vol. vii. pp. 73, 74.

by that gentleman, was most destructive to platinum, and it was for that reason, no doubt, that he suggested the use of porcelain instead.

After carefully considering how Dr. Clark's reagent behaved, I concluded that the reason caustic is so active is because it readily melts and perfectly surrounds each particle of the chrome powder, and the magnesia being infusable keeps the mass porous and open to oxidation, the oxygen of the hydrate contributing no doubt in some measure to the chrome.

Magnesia, or lime and carbonate of soda, do not act near so rapidly, neither do the earth bases with carbonate of potash alone, due no doubt to the infusibility of the carbonates.

The two carbonates, soda and potash, when mixed, melt at a lower temperature than when separate. It was thought, therefore, that such a mixture, together with lime or magnesia, would approximate most closely to the caustic reagent, and might be heated in platinum vessels to most elevated temperature without damaging them, and rapid oxidation result.

On trial this proved to be the case, for by its means rich ferro-chromes were found to be most readily oxidised, and the chrome in chrome iron ore quickly converted into chromic acid.

The following results will show this to be the case.

Several portions of 0·624 grms. of ferro-chrome, after pounding for ten minutes in an agate mortar, were each mixed with 7 grms. of the tribasic reagent; the several portions were introduced into platinum crucibles, and were heated for varying periods of time to bright redness at the back of a Griffin's muffle furnace, and the chromium oxidised in each was determined.

		Chromium in Ferro-Chrome.
No. 1	5 minutes	60·62 or 97·60 per cent.
No. 2	60 minutes	61·94 „ 99·92 „
No. 3	2 hours.	61·99 „ 100·00 „
Clark's method		61·99 „ 100·00 „

Several portions of chrome ore were treated in a similar way and yielded—

		Chromium in Chrome-Ore.
No. 1	5 minutes	30·70 or 89·00 per cent.
No. 2	60 minutes	34·50 „ 100·00 „
No. 3	2 hours.	34·49 ...
Clark's method		34·45 ...

In each case the chromic acid was determined with a ferrous solution and bichromate of potash.

The following determinations were made by the Hypo-Aceto Volumetric method, titrating with permanganate in sulphuric acid solution.

Chromium in British Iron and Steel, etc.

The results were obtained on working on from 5 to 10 grammes of material:—

Pig Iron.

District.	Chromium. Per Cent.
Glengarnock Forge	0·016
1. Do. Basic	0·028
2. Do. Do.	0·035
Carnforth Hæmatite	0·013
Wellington No. 1.	0·058
Holwell	0·120
Lincolnshire No. 3.	0·017
Forest of Dean No. 3.	0·008
Silverdale	0·011
Lilleshall Cold Blast	0·010
Welsh Foundry	0·014
1. Cleveland No. 3.	0·051
2. Do.	0·064
3. Do.	0·069
4. Do.	0·059
Cleveland Hæmatite, from Spanish Ore	0·008
2. Do.	Nil
1. Cleveland Basic iron made with Cleveland ore, manganese ore, and forge conder	0·110
2. Do. Do.	0·096
3. Do. Do.	0·085

Steels.

District.	Chromium. Per Cent.
Sheffield from Cumberland Hæmatite	0·006
Swedish	Nil
1. Cleveland Basic Steel	0·010
2. Do. Do.	0·008
3. Do. Do.	0·012

Basic and other Slags.

District.	Chromium. Per Cent.
Leeds Basic Bessemer	0·108
Parkgate Basic Open Hearth	0·155
Wigan Basic Open Hearth	0·133
Cleveland Basic Bessemer	0·190
Single sample of Cleveland Forge Cinder	0·290
Cleveland Blast Furnace Slag	Nil

Chromium in the Puddling Process.

A charge of Clarence iron was carefully sampled at the works of Messrs. John Hill & Co., Middlesbrough, and was then puddled in the usual way, and samples of the puddled bar and of the cinder were taken and were analysed, with the following results, viz. :—

Description.	Clarence Pig. Per Cent.	Forge Slag. Per Cent.	Puddled Bar. Per Cent.
Chromium	0·057	0·290	0·004

The fettling was not examined, but it is clear that chromium is almost completely removed from iron by fluid oxides of iron.

The following results by the hypo-aceto method are by one of my pupils, Mr. J. Henderson, who is now analyst at the works of Messrs. W. Whitwell & Co., and were obtained on testing the products from a puddling furnace at the Thornaby Iron Works :—

Description.	Weight.	Chromium. Per Cent.
Pig Iron	5 0 0	0·067
Fettling	1 1 10	0·010
Puddled Bar	4 3 5	0·016
Tap Cinder	1 2 4	0·184

Chromium in the Basic Bessemer Process.

Samples of iron, steel, and slag from the Glengarnock Works were kindly provided to me by Mr. Jos. Walton, and these were carefully examined for chromium :—

Description.	Pig.	At Commencement of the Blow.	Before the After Blow.	After the After Blow.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Chrome in metal . . .	0·035	0·022	0·016	0·018
Do. in accompanying slag .	...	0·038	0·102	0·100

Vanadium in Pig Iron.

The methods of determining vanadium are receiving careful consideration, and it is hoped that before long I shall be able to place before this Institute the results obtained.

So far as I have gone it has been found that in British pig irons it invariably accompanies chromium, also that a considerable proportion of that present in pig iron is not obtained in solution on treating with hydrochloric and sulphuric acids.

The following results will be of interest, viz.:—

Description.	Vanadium.		
	Soluble.	Insoluble.	Total.
	Per Cent.	Per Cent.	Per Cent.
Clarence Pig Iron	0·120	0·063	0·183
Cleveland Pig Iron	0·100	0·162	0·262
Cleveland Pig Iron	0·048	0·213	0·261
Holwell Pig Iron	0·076	0·110	0·186
Lincolnshire Pig Iron	0·080	0·088	0·168

The vanadium is most readily detected qualitatively in the insoluble residue by heating it with the magnesia mixture or the tribasic reagent, extracting with water, and after filtering and acidulating with sulphuric acid and adding a few drops of peroxide of hydrogen.

If vanadium is present, the solution assumes a deep red colour, which is dissipated on boiling.

VOTES OF THANKS.

The PRESIDENT said it was now his duty to move the following resolution:—"That the thanks of the Iron and Steel Institute be and are hereby tendered to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their rooms, and for the facilities otherwise accorded for the present meeting.

Mr. JEREMIAH HEAD seconded the motion, which was unanimously agreed to.

Sir HENRY BESSEMER said there was one other duty they had to perform, and he was sure it would be a pleasurable one. He rose to propose:—"That the cordial thanks of the Iron and Steel Institute be and are hereby tendered to the President for his admirable conduct in the chair."

Mr. WILLIAM ROBERTS seconded the motion, which was carried unanimously.

The PRESIDENT said he heartily thanked the members for their acknowledgment of his services, and he hoped they would regularly attend the meetings, volunteer papers, and contribute to the discussions.

OBITUARY.

William George Ainslie, born in 1832, in India, was educated at Sedbergh School. He was originally in the service of the East India Company, and at the time of his death was senior partner in the iron and steel manufacturing firm of Messrs. Harrison, Ainslie & Co., of Ulverston, and chairman of the North Lonsdale Iron and Steel Company, Limited, of the same place. Notwithstanding his many business engagements, he found time to interest himself in public affairs. He was a magistrate for Lancashire, and in 1885 and 1886 member of Parliament for the North Lonsdale division of that county. When in Parliament, he took an active part in the promotion of the Pig Iron Warrants Bill. He took great interest in the Volunteer movement, and formerly held a commission as captain in the 37th Lancashire Volunteers. He was an original member of the Iron and Steel Institute, and was present at the inaugural meeting in London on June 23, 1869. Mr. Ainslie died in February last, and was thus sixty-one years of age.

Edward Carr, who was elected a member of the Iron and Steel Institute in 1883, died in March last at the early age of forty-seven. He had been connected with the iron trade for nearly twenty years, and at the time of his death was acting as the London representative of Messrs. Ibbotson Brothers & Co. of Sheffield.

Edward Alfred Cowper, son of Edward Cowper, the improver of the printing-press, and Professor of Engineering at King's College, was born on December 10, 1819. He was apprenticed in 1834 for seven years to Mr. John Braithwaite of London, and in 1846 he was engaged by Messrs. Fox & Henderson of Birmingham. In 1851 he was occupied with the contract drawings for the buildings of the Great Exhibition, and in that year started practice as a consulting engineer in London.

Mr. Cowper designed the roof of the Birmingham Railway Station, the first large-span (211 feet) station roof constructed. He was a fertile

inventor. During his apprenticeship he invented the well-known railway fog-signal, and, when engaged with Messrs. Fox & Henderson, he invented an improved method of casting railway chairs. In 1857 he patented his regenerative firebrick hot-blast stove, and continued to introduce improvements in its construction until 1887. Amongst his other inventions may be mentioned a compound engine with receiver patented in 1857, a bicycle wheel with steel spokes and india-rubber tire, patented in 1868, and an electric writing telegraph, patented in 1879.

Mr. Cowper was an original member of the Iron and Steel Institute, and a constant contributor to its publications. In 1847 he assisted in founding the Institution of Mechanical Engineers, and in 1880-81 occupied the presidential chair of that body. He was a member of the Council of the Institution of Civil Engineers, and in 1884 was selected by them to give a special lecture on the steam-engine. He was commissioned by the Science and Art Department to catalogue the collection of machinery and inventions in the South Kensington Museum.

Mr. Cowper died on May 9, 1893, after a short illness, the cause of death being attributed to pneumonia.

Rowland Winn, Lord St. Oswald, whose death occurred on January 19, 1893, was a large owner of iron ore royalties in the Lincolnshire district. He was born in 1820, and created first Baron in 1885. He was elected a member of the Iron and Steel Institute in 1887.

Frederick Ransome, who died at the age of seventy-five on April 19 last, at his residence in East Dulwich, was elected a member of the Iron and Steel Institute in 1887. He was best known as the inventor of a successful process for the manufacture of artificial stone. He also applied the same process to the manufacture of emery wheels, one of which, according to the *Iron and Coal Trades Review*, ground away ¼ oz. of steel in sixteen minutes, as compared with eleven hours taken by a Newcastle grindstone, both pieces of steel being cut off the same bar. Mr. Ransome was greatly interested in the utilisation of blast-furnace slag, and paid much attention to the manufacture of cement from that material.

Matthew Henry Simpson, born on August 12, 1853, was educated at Birkenhead Proprietary School. After serving articles for six years with Messrs. Laird Brothers of Birkenhead, he became in 1879 managing

partner in the firm of Messrs. Sharp & Co., of the Phœnix Foundry, Lancaster. Feeling in the management of that foundry the lack of theoretical knowledge, he entered the metallurgical laboratory of the Royal School of Mines, where he passed the examinations in a highly satisfactory manner. Having a decided taste for original research, he spent a large portion of his time on returning to Lancaster in metallurgical investigations, more particularly in connection with the properties of iron and steel. Mr. Simpson's work at the Phœnix Foundry ceased in 1886, when he dissolved partnership. Subsequently he devoted his time to the metallurgy of gold and silver, and on February 29, 1892, fell a victim to the unhealthy climate of British Guiana, where he had charge of an exploratory expedition he had organised for mining alluvial gold deposits. In 1888 he patented an improved process for the extraction of gold from its ores, and he had previously taken out, in conjunction with Mr. F. Sharpe, a patent for a machine for breaking pig iron. Mr. Simpson was an Associate Member of the Institution of Civil Engineers, and in 1885 was elected a member of the Iron and Steel Institute.

Henry Woolcock was born in Cornwall in 1842, and in 1861 proceeded to Westmoreland, where he occupied the position of assistant-manager at the Greenside lead mines. From 1863 to 1866 he was engaged at the Hartsop Hall and Myres Head mines. In 1866 he undertook, for the late Mr. Hannay, the management of his hæmatite mines and collieries. In 1873 Mr. Woolcock started in business on his own account in Whitehaven as a mining engineer. From that time to the day of his death in 1892 he had a very good local practice. He had the management of the Asby Colliery, of High Houses iron mines, and of Falcon iron mines. He was also consulting mining engineer to the Whicham Mining Company, the London and North-Western and Furness joint railways, and the Millom and Askam Hæmatite Company. He was elected a Member of the Iron and Steel Institute in 1889.

John Head was born in Birmingham on April 11, 1839, but he did not long remain in his natal town, as he was removed to France when he was four years of age. Here he was educated, and here he first began business, having been engaged as a banking clerk before his return to England. In 1858 he carried on business in England on his own account as an agent for the sale of steam engine fittings. In

1859, Mr. William Siemens was agent in this country for the Berlin firm of Siemens and Halske, and engaged Mr. Head as clerk. In 1860 he was employed as Mr. Siemens' personal assistant, and he continued in that gentleman's employment until his death as Sir William Siemens in 1883, when, on the transfer of the business to Mr. Frederick Siemens, Mr. Head was appointed general representative for Great Britain, France, Belgium, Spain, Portugal, and the United States of America and their colonies. During the period of his employment by the late Sir William Siemens and Mr. Frederick Siemens, he was actively engaged in this country and abroad, in superintending the design, construction, and working of regenerative gas furnaces, and their application to processes for the manufacture of steel, and of glass, as well as to the ordinary metallurgical processes of heating and puddling iron.

During the last eight years Mr. Head has read papers before the Iron and Steel Institute and other societies. In the beginning of 1885, he brought Mr. Frederick Siemens' process of heating by radiation before the South Staffordshire Institute of Iron and Steel Works Managers. In 1886 he read a paper on blow-holes in open hearth steel before the Iron and Steel Institute, in which he brought forward evidence to show that blow-holes were found in glass or steel melted in furnaces in which the flame came in contact with the materials being treated, whilst this was not the case when heating by radiation was adopted. In 1887 he read a paper before the Sanitary Congress at Bolton on the application of this system of heating to gas-fired boilers. In 1885 he brought before the Iron and Steel Institute a paper on "A Modified Form of the Siemens Old Type Gas-producer," advocating an arrangement by which the gases are enriched, and the by-products recovered.

In 1889, Mr. Head and M. Pouff, who was at that time Mr. Siemens' representative in Paris, read a paper at the Paris meeting of the Iron and Steel Institute, which was discussed in 1890, on a new form of Siemens furnace arranged to recover waste gases as well as waste heat. This furnace was designed by Mr. E. Biederman and Mr. E. W. Harvey. According to this invention, a certain proportion of the waste products of combustion are supplied hot into the incandescent fuel of the gas-producer, and the carbonic anhydride of these waste products is thus converted into carbonic oxide, by which a considerable economy in fuel is realised. The gas-producer in the new form of Siemens furnace partly takes the place of the gas regenerator in the original Siemens furnace, so that the new form permits of the suppression of the gas

regenerators, the placing of the gas-producer close to the furnace, and a simplification and economy in construction.

At the last meeting of the Iron and Steel Institute, Mr. Head read a paper entitled "Notes on Puddling," which is published in this volume. Although for years past Mr. Head has suffered from bad health, and was attacked by influenza three years ago, his sudden death from pneumonia, which took place after six days' illness, was a shock and surprise to all who knew him. He died on July 14, and was interred at St. Mary's Cemetery, Kensal Green, on the 20th. Mr. Head was a Fellow of the Geological Society, and a member of the Institution of Civil Engineers. He was elected a member of the Iron and Steel Institute in 1884.

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

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ABSTRACTORS.

EDWIN J. BALL, PH.D.

BENNETT H. BROUGH, ASSOC. R.S.M.

IRON ORES.

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I.—*OCCURRENCE AND COMPOSITION.*

Theories of the Origin of Iron Ores.—Mr. H. V. Winchell* gives the following classification of the theories of the origin of iron ores:—

A. Mechanical:—

a. Extra-terrestrial or cosmical: 1. Meteoric fall.

b. Terrestrial: 1. Subterranean, eruption in dykes or accompanying basaltic flows; 2. Superficial action, (a.) violent abrasion and transport; (b.) ordinary erosion (*α.* concentration of iron sands; *β.* oceanic sedimentation).

B. Chemical:—

a. Changes *in situ:* 1. Change in the kind or quantity of iron already present in the rocks, (a.) alteration of diffused ferric oxide into ferrous carbonate; (b.) metamorphism of bog ore; (c.) metamorphism of lake ore; (d.) alteration of ferrous carbonate or sulphide into ferric oxide; 2. Change in the kind or quantity of other minerals; (a.) substitution of iron oxide for some non-ferriferous mineral; (b.) concentration by removal of the other constituents; (c.) electro-telluric action.

b. Removal by chemical action and subsequent deposition: 1. By action of heat (sublimation); 2. By action of water; (a.) in drainage basins, by oceanic precipitation, or as a secondary product of the decomposition of basic rocks or of pyrites; (b.) in the rocks, by saturation of porous strata, or by infiltration into cavities; (c.) deposited by springs.

The Iron Ores of Great Britain and Ireland.—In a volume covering 430 pages, Mr. J. D. Kendall† gives a systematic and careful

* *The American Geologist*, vol. x. pp. 277-278.

† "The Iron Ores of Great Britain and Ireland." London, 1893.

account of the present knowledge of the origin and occurrence of the iron ores of Great Britain and of the means of working them. A brief description is also given of the early working of the ores in this country. The second part of the volume deals with the geological position, form and nature of iron ore deposits, chapters being devoted to the hæmatite deposits of West Cumberland and Furness, to the iron ores of Cornwall, Devon, and West Somerset, to the limonites of the Forest of Dean and South Wales, to the siderite and limonite of Alston and Weardale, to the argillaceous ironstones of the carboniferous strata, to the iron ores of the secondary rocks, and to the iron ores of Antrim. In a supplementary chapter a considerable amount of information is introduced with reference to some of the more important ores of Spain. The third part of the volume deals with the age and origin of the deposits, whilst the fourth part is devoted to a consideration of the methods employed in searching for and working iron ore deposits. The text is elucidated by forty-one illustrations and by five folding plates.

Austrian Iron Ores.—Dr. E. Prziwoznik* gives the following results of analyses of iron ores conducted in the laboratory of the Government Assay Office in Vienna:—

1. Iron ores from the mines of the Austrian Alpine Company: (*a.*) hæmatite; (*b.*) ordinary limonite; (*c.*) compact limonite passing into oolite; and (*d.*) oolitic iron ore:—

Description.	*a.*	*b.*	*c.*	*d.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ferric oxide	75·90	73·50	38·83	28·85
Alumina	3·12	11·71	35·87	46·15
Manganic oxide	0·21	0·57	trace	trace
Copper	0·03	trace	0·01	0·01
Lime	0·95	0·82	1·35	1·40
Magnesia	0·40	0·40	0·52	0·58
Silica	18·35	8·10	13·50	12·90
Phosphoric anhydride	0·07	0·02	0·10	0·03
Sulphuric anhydride	0·30	0·38	0·38	0·44
Water	1·00	4·80	10·00	10·30
Totals	100·33	100·30	100·56	100·66
Iron	53·10	51·45	27·18	20·20
Manganese	0·15	0·41	trace	trace
Phosphorus	0·03	0·01	0·04	0·01
Sulphur	0·12	0·15	0·15	0·17

2. Spathic iron ore from the Peter Tunner level of the Söberhaggen mine at Eisenerz. 3. Brown hæmatite from the Ruszkitza mine. 4.

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 458-46.

Red hæmatite from the Trofaiach ironworks. 5. Magnetite from the same works :—

Description.	2.	3.	4.	5.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ferrous oxide	46·41	0·50	3·98	29·08
Ferric oxide	3·86	66·31	60·43	52·50
Manganous oxide	3·50	3·10	3·15	...
Copper	trace	0·01	0·07	...
Alumina	...	1·59	0·64	trace
Lime	2·10	1·50	2·40	2·50
Magnesia	3·61	0·77	2·63	0·30
Silica	5·10	14·70	8·35	4·75
Carbonic anhydride	34·80	...	3·60	9·10
Sulphuric anhydride	0·22	...	4·25	0·86
Phosphoric anhydride	0·06	0·21	0·06	1·19
Loss on ignition	...	11·00	...	...
Barytes	...	...	7·42	...
Water	...	...	2·80	...
Organic matter	...	...	0·21	...
Totals	100·36	100·19	100·00	100·28
Iron	38·80	47·15	45·40	59·31
Manganese	2·72	2·40	2·27	...
Phosphorus	0·02	0·08	0·02	...
Sulphur	0·37	0·27	1·70	0·34

Luxemburg Iron Ore.—In the neighbourhood of Esch there are four deposits of brown hæmatite. The upper one is rarely worthy of exploitation, as it contains a large percentage of silica. Below this, at varying depths, follows a bed of red ore 6 feet thick, then, at a farther depth of 36 or 40 feet, follows another bed from 8 to 16 feet of a grey ore, and at a still greater depth another bed of a brown ore from 8½ to 10 feet thick. The beds are horizontal, or only very slightly inclined. The percentage of iron in these three lower beds of ore varies from 36 to 39 per cent. The cost of the ore f.o.b. at Esch is only 2s. a ton. The number and thickness of these beds of minette ore decreases from the north towards the south. According to J. G. Jungner,* estimates place the duration of the German Lorraine ore deposits at 750 years, the annual output remaining as at present, while the Luxemburg deposits will last for 100 years.

Iron Ore in Poland.—In the course of an elaborate report on the industrial resources of Western Russia, J. Couharevitch † gives full details of the occurrence of iron ore. The Carboniferous strata include

* *Jernkontorets Annaler*, vol. xlvi. pp. 156–163.
† *Revue Universelle des Mines*, vol. xix. pp. 265–335.

beds of clay iron ore averaging 35 per cent. of iron, whilst the iron ores of Triassic age occur in great profusion at the edges of the Dombrowa basin. The ore is limonite, and contains as much as 40 per cent. of iron. There is also a bed of spherosiderite in mammelated masses covered by a bed of sand and clay. A specimen of this ore from Zarki gave on analysis the following results :—

CO_2.	SiO_2.	Al_2O_3.	CaO.	MgO.	P_2O_5.	S.	MnO.	FeO.
35·48	5·48	3·55	10·00	3·40	1·14	0·04	0·56	40·37

The Devonian rocks contain iron ore with 40 per cent. of iron. The existence of iron ores of the various geological formations has been proved over an area of 3800 square miles. Some of the deposits are, however, unworkable on account of hydrographic conditions, the cost of raising the water being out of proportion to the value of the ore. The workings are either open-cast or shallow mines with shafts and levels. About a hundred mines are being worked, the output being used for twenty charcoal and seven coke blast-furnaces.

Iron Ore in the Central Urals.—A. Saitzew * gives an account of the various metalliferous deposits of economic importance that occur in the Nicolai-Paudinsch district of the Central Urals. Amongst other minerals, red and brown iron ores are found. These are met with n contact deposits, between porphyry and limestone. Dolomite also occurs.

The Iron Ore Deposits of Spain.—The iron ore deposits of the South of Spain † may be divided into seven groups :—

Group.	Character of Ore.
1. Carthagena and Portman .	Hæmatite and manganiferous.
2. Parazuelas	Red hæmatite.
3. Aguilas	Red hæmatite.
4. Garrucha and Bedar . .	Hæmatite and manganiferous.
5. Almeria	Hæmatite.
6. Malaga and Marbella . .	Magnetite.
7. Calasparra and Cehegin .	Magnetite.

The first of these groups is the one that has been most developed in the past. This is due to the ores containing from 14 to 21 per cent. of manganese, and being consequently well adapted for the manufacture of

* *Mémoires du Comité Géologique*, vol. xiii. p. 83.
† *American Manufacturer*, vol. lii. p. 65.

spiegeleisen and ferro-manganese. The cost of the ton of ore delivered at Portman has usually been under 5s. More than 7,000,000 tons have been mined. Recently there have been shipments of ore on a scale of some magnitude from the mines near Almeria, a port between Malaga and Carthagena. The mines are about twelve miles from the harbour, and are connected with it by a railway. Some manganese is present in the ores of this district, but the quantity is not sufficient to impart much extra value. The ore in sight is estimated to be between 25,000,000 and 35,000,000 tons. Another large deposit occurs among the mountains of Calasparra, about sixty miles from Carthagena. There is, however, no railway communication. This ore contains between 55 and 60 per cent. of iron.

The Origin of the Gellivara Ores.—H. von Post* is of opinion that the iron ores of Gellivara and of other localities in the province of Norbotten are connected in their origin with the eruption of the gabbro met with in the vicinity. They are therefore eruptive. He points out that the gabbro near the Gellivara ore mountain is rich in iron ore. Indeed, on the assumption of 5 per cent., it contains more iron ore than the ore mountain itself. Other gabbro masses, too, are enclosed in rocks in which iron ore occurs. Further, the gabbro masses and the ore mountain contain apatite in large quantities, together with various titanium minerals, and are traversed by numerous veins of hornblende and pegmatite. The rock in which the Gellivara ores occur, though apparently resembling gneiss, is in reality a granite, whose schistose character is due to the great pressure to which it has been subjected. That the strike and dip of the ore bodies coincides with those of the surrounding rock, may be a result of this mountain pressure. For when this pressure exceeded the cohesion of the rocks, fissures were formed which received the iron ore, and which assumed a direction parallel to that of the lamination of the rock. The occurrence of apatite, titaniferous minerals, and hornblende as matrix with corundum, desmine, and fluorspar occurring subordinately, is characteristic of the Gellivara deposit. All these minerals are, however, characteristic of eruptive deposits. The large ore bodies consist in the centre of specular iron ore and on the edges of magnetite. This condition is due to the reduction of the ferric oxide deposited by eruption in the fissures. Numerous veins of granite and pegmatite met with also afford evidence of the eruptive origin of the ore.

* *Geol. Föreningen i Stockholm Förhandlingar*, vol. xii. p. 491.

The Formation of Iron Ore Deposits.—In a volume covering 151 pages, and elucidated by two maps and numerous illustrations, Professor J. H. L. Vogt* discusses the genesis of two groups of Norwegian and Swedish iron ores. The first of these is the titaniferous iron ore formed by concentration in basic eruptive rocks. The second group is termed by the author the pneumatolytically formed iron ores. To this belong deposits of magnetite and specular iron ore as well as certain deposits of ores of other metals. Except the Christiania granite contact deposits and the Langö granite specular iron ore albite veins, both of which are of but slight economic importance, no iron ores are as yet known in Norway and Sweden that have been formed by pneumatolytic processes. Indeed, throughout the world this group appears to be very sparingly represented. The iron ores produced by solfataric processes, like those of the Christiania district, are characterised by a fairly high percentage of sulphur.

Iron Ore in Canada.—According to Mr. R. A. Parker,† there are some localities in Canada now attracting considerable attention. They are Aticokan, Arrow, and Gunflint Lakes. Laurentian gneisses have been traced for some distance, and on the south side deposits of hæmatite of Bessemer grade have been found in the Animikie states. The gabbro contains deposits of ore lying horizontally, as if they filled the synclinal folds, the ore consisting partly of magnetite, often with a considerable percentage of titanium. A railway is being built. The commercial effect of the output of these ores is considered by the author.

The first of these deposits is about sixty miles from the lakes, according to Mr. W. W. Russell,‡ who states that titanium is seldom present, and that an analysis by Dr. R. C. Selwyn of ores from Gunflint Lake contained 61·08 per cent. of metallic iron and 19·65 per cent. of insoluble matter with no titanic acid. Other details are also given by various writers,§ and Dr. R. W. Raymond explains the high percentage of iron, taking into consideration the insoluble matter, by the supposition that the magnetic oxide may contain an excess of ferrous oxide.

Iron Ore in Ontario.—According to Dr. R. Bell,‖ of the Geological Survey of Canada, small isolated deposits of magnetite and hæmatite

* *Om dannelse af jernmalmforekomster.* Christiania, 1892.
† *Engineering and Mining Journal*, vol. liv. p. 561.
‡ *Ibid.*, vol. liv. p. 627.
§ *Ibid.*, vol. lv. pp. 28, 74, 122, 170.
‖ *First Report of the Bureau of Mines of Ontario*, pp. 87–88. Toronto, 1892.

have been found among the quartzites of the La Cloche region, but none appears to be sufficiently extensive to justify mining operations. The ores are free from titanium, phosphorus, and sulphur, and it is to be hoped that further explorations among these rocks may bring to light larger masses of iron ore.

Thin veins of good magnetite, accompanied by quartz, occur in the red hornblende granite near Cartier Station and on the Spanish River. The granitic districts, however, do not appear to be promising for iron ores.

On Iron Island, in Lake Nipissing, small masses of specular iron are common to most of the rocks in the island, and in the crystalline limestone there is a very great display of it. In the Huronian iron-bearing region of Lake Superior the ores have two different modes of occurrence. In the one case they are associated with hornblendic or chloritic schists, which appear to belong near the base of the system, and in the other they occur with fine-grained siliceous and jaspery rocks. The magnetite of the Aticokan region is an example of the first, and that of Hunter's Island and Kaministiquia River of the second.

Mr. T. D. Ledyard * gives the following analyses from various sources of magnetic iron ore from the Belmont Mine in Ontario :—

Iron.	Phosphorus.	Sulphur.	Titanic Anhydride.	Silica.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
65·10	0·005	0·07	0·04	3·83
66·23	0·013	0·016	...	3·88

In various localities near Devil's Lake considerable quantities of ore have been found with contents as follows :—

Iron.	Phosphorus.	Sulphur.	Titanium.
Per Cent.	Per Cent.	Per Cent.	
62·26	0·009	0·052	None.
69·25	0·012	0·038	Trace.

Mr. W. Molin † gives the following analysis of magnetic iron ore from a large deposit situated at Belmont, about a hundred miles east of Toronto :—

* *Engineering and Mining Journal*, vol. lv. p. 322.

† *Ibid.*, vol. liv. p. 484.

Fe.	SiO_2.	Al_2O_3.	CaO.	MgO.	TiO_2.	P.	S.
65·10	3·83	2·35	2·93	0·03	0·04	0·005	0·07

No manganese or copper is present. Some samples contain as much as 70 per cent. of metallic iron.

The Iron Ore Deposits of Nova Scotia.—In a paper read before the Mining Society of Nova Scotia at their February meeting, Mr. E. Sjostedt observed that between Springville and Sunny Brae, Pictou, Nova Scotia, iron ores occur as contact deposits between the Carboniferous limestones and Upper Silurian measures. They are mostly brown hæmatites, more or less mixed with pyrolusite in the form of nodules or masses. This occurs chiefly on the hanging wall, but also as veins or crystals in the deposits themselves. Specular ores occur on the south side of the East River. The following are analyses of ores from this district. The first or "gravel" ore occurs in the form of a seam 10 or 15 feet in width; the second is a solid limonite, and is in places 18 feet thick:—

Description.	Gravel Ore.		Compact Ore.	
	1.	2.	1.	2.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Insoluble matter . . .	12·80	6·75	8·58	5·58
Iron	45·02	53·41	54·83	56·57
Manganese	1·56	1·88	0·20	0·20
Combined water . . .	9·45	11·02	10·00	10·90
Sulphur	0·05	0·04	0·41	0·09
Phosphorus	0·12	0·02	0·03	0·21

These deposits are only a few hundred feet above the blast-furnace where they are smelted, and the haulage is consequently very cheap. So, too, is the mining, which is effected by means of adits. The second or "compact" limonite is fibrous in character, and requires blasting, which the "gravel" ore does not.

Iron Ore in New Zealand.—In dealing with the several minerals that have been found and worked in New Zealand, Mr. G. J. Binns* shortly notes the various occurrences of manganese ores, which are plentiful in the colony. Rich chromite has also been found and worked in variable quantities. Of iron ores, the granular varieties or iron-sands are very widely distributed, especially on the west coast of both islands. The following massive ores, amongst others, have also been examined:—

* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 59–82.

Locality.	Magnetite.	Hæmatite.	Siliceous Matter.
	Per Cent.	Per Cent.	Per Cent.
Manukau, Auckland . .	60·20	37·9	1·90
Interior of Otago . . .	86·32	...	13·68
Lake Wakatipu, Otago .	96·11	...	3·89
Nelson mineral belt . .	...	90·6	7·60

In the Tertiary coal formation of Raglan, near Auckland, brown ore is found with the following composition :—

Ferric Oxide.	Oxide of Manganese.	Alumina.	Lime	Magnesia.
72·69	0·56	1·16	0·27	0·69

Phosphoric Anhydride.	Sulphide of Iron.	Siliceous Matter.	Water.
0·70	trace.	6·30	17·63

A hydrated ferric oxide is found in large quantities on the surface near Collingwood, Nelson, and appears to be the capping of a pyritic vein. A sample gave :—

Ferric Oxide.	Manganese.	Lime.	Magnesia.	Siliceous Matter.	Water.
62·68	trace.	0·61	trace.	23·47	13·24

Iron manufactured from this ore contained :—

Fe.	Mn.	C.	Si.	Ti.	P.	S.
97·668	0·268	0·750	1·004	trace.	0·041	0·269

Close by this deposit is an abundant supply of pure limestone, and the Collingwood coal-mine is only five miles away. A similar deposit has been found at Mount Peel, Nelson. Spathic ore, of which a detailed analysis is given, is found in the Collingwood Colliery, and other pure spathic ores have been found in two other collieries. Some account is then given by the author of the various attempts that have been made to manufacture iron in the colony.

The Menominee Iron Ore Range.—According to Mr. D. Hulst,* who gives a description of the geology and characteristics of the eastern portion of the Menominee Range, it appears that its productive portions are, to a certain extent, situated at or near points where the geological formation has been faulted, eroded deeply, or sharply folded. One of these features occurs in close proximity to the Iron Mountain and the mines at Pewabic, Quinnesec, Norway, Aragon, and elsewhere. The ore

* Paper read before the Lake Superior Mining Institute; *Engineering and Mining Journal*, vol. lv. p. 366.

bodies are invariably associated with lean jaspery ores; although the former may fill the whole deposit, yet at its edges the lean ore reappears. In some places the transition stage is seen. As a rule, the ore bodies pitch to the west at 30° to 50°, which may be accounted for if they were deposited before the uplifting of the Huronian rocks. Until lately, all productive ore bodies have been found above the limestone, but the deposit at the Loretta mine has recently been found underlying the limestone and producing ore of high grade. The ore lenses may be found at any geological height in the jaspery beds. Some of these have no definite walls, and in that case the percentage of phosphorus is sure to be low. It would also appear that ore immediately underneath the drift has lost more or less of its phosphorus by leaching, and there is a settled conviction among the chemists that phosphorus does leach out during a winter's exposure on the stock pile. All the mines in the eastern portion of this range, except the Norway Mine, produce the soft blue hæmatite, a kind of specular ore, but the ore from each mine has slight distinctive features by which it can be identified.

The Mesabi Iron Ore Range.—The ore formation of the Mesabi Range, as described by Mr. H. V. Winchell,* covers an area from one to two miles broad and 140 miles long.

Prospecting is done by sinking pits to a depth of more than 100 feet. If ore is found, the amount of water is to a certain extent an indication of the size of the ore body. Usually much water is found in the lower parts. For mining the ore, the surface is stripped, and the ore is got in the open. The ore has sometimes to be blasted, but there is more soft than hard ore, and it can be worked by hand or by steam excavators. The minimum cost is 5·6d. for getting and loading a ton of ore, and the average is rather under 1s. 3d. A large number of analyses of the various ores are given, with particulars of the mines opened up in the district.

The first body of soft hæmatite discovered in the present important iron ore field of the Mesabi Range† was struck on November 16, 1890, in a test-pit on the north-west quarter of Section 3, Township 58, Range 18 West of the fourth principal meridian. This is now known as the Mountain Mine. Hard ore, chiefly magnetic, had been known to exist in small quantities for some years previous to the discovery of the present

* *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

† *Twentieth Annual Report of the Minnesota Geological Survey; Iron Age*, vol. 1. pp. 1271–1273.

known large ore bodies. The ore formation of the Mesabi Range extends from the Canadian boundary-line for a distance of 140 miles through Minnesota, in a direction a little south of west to and beyond the Mississippi River. For a portion of this distance the ore-bearing rocks are concealed by gabbro. The width of the ore belt at no place exceeds, it is thought, about two miles, and is usually less than one. The ore lies in nearly flat beds, having a variable thickness up to 100 feet. The ore deposits are found at irregular intervals. At the eastern end of the range the ore is hard, black, and magnetic, due, it may be, to the gabbro overflow. On the central and western portions of the range the ore is partly soft hæmatite, limonite, and göthite, with hard hæmatite and limonite streaks of variable thickness. The rocks exposed on the Mesabi Range are the following in descending order:—

1. Gabbro, unconformable on all the following	Taconic.
2. Black slates—Animikie	Taconic.
3. Greenish silicious slates and cherts	Taconic.
4. Iron ore and taconite horizon	Taconic.
5. Quartzite unconformable on 6 and 7	Taconic.
6. Green schists of the Keewatin	Archæan.
7. Granite or syenite of the Giant's Range	Archæan.

Resting immediately upon the basal quartzite, and apparently conformable with it, is a series of strata which present very different appearances in different localities, and which constitute the iron ore deposits in situations favourable for their accumulation. These strata consist of siliceous and sometimes calcareous rocks banded with oxide of iron or iron ore. The ore occurs in streaks or beds of indefinite length and thickness. It is sometimes magnetite, sometimes hæmatite, hard or soft. The rock which encloses these bands may be called a jaspery quartzite, but it contains much besides silica. It is of various colours, but usually grey. It is occasionally cherty, often brecciated, and sometimes conglomeritic.

It has been named taconite, and although the percentage of iron occurring in it in its unaltered form is small, yet it is found in all stages of alteration into ore of merchantable grade. This banded jaspery quartzite or taconite horizon is not of great thickness. There is a rather abrupt transition below into quartzite, and a more gradual one into the siliceous slate and chert members above. The ore deposits are bedded, and as a rule lie directly on the softened and disintegrated basal quartzite. The bedding-planes of the original strata are perfectly preserved in the ore, as are the joints, and even the differences in texture of the various layers of jasper, chert, coarse and fine taconite, and slate. The ore

deposits are occasionally found in glacial gorges. A test-pit has been sunk to a depth of 72 feet at the side of one of these gorges on the Beringer mine. The eastern half of the pit passes through soft blue hæmatite from the depth of 48 feet to that of 72 feet, while the west half of the pit is in sand and gravel between these depths. A short distance farther west a deeper test-pit did not strike ore.

The author next considers the question of the origin of the ore deposits of the Mesabi Range. He believes them to be due to the replacement of older beds by aqueous action. He also considers the quality of the ore found, and gives a large series of analyses, among which are the following:—

Mine.	Iron.	Silica.	Phosphorus.	Manganese.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Beringer	60·97	6·05	0·067	...
Biwabic	63·70	3·46	0·046	0·284
Canton	60·21	4·20	0·059	...
Cincinnati	58·30	8·95	0·050	0·791
Great Western	64·36	...	0·022	...
Hale	60·67	4·05	0·074	1·079
Kanawha	60·95	5·52	0·066	0·600
Lone Jack	58·40	6·42	0·092	0·478
M'Kinley	62·46	8·03	0·021	0·770
Mesabi Mountain	61·73	5·07	0·055	0·542
Mountain	63·22	5·64	0·050	0·155
New England	60·90	6·02	0·050	...
Ohio	63·16	5·34	0·036	0·432
Approximate averages	61·46	5·92	0·053	0·667

There was also an average percentage of combined water, amounting to 4·063, and of hygroscopic moisture, amounting to 6·886. A large number of assays and results are given in the case of each mine, and especially that of the Biwabic, in which the highest percentage of iron recorded is 67·90, and the lowest 50·85.

The Mountain iron mine in the Mesabi iron ore range was discovered in 1890 by ore being observed in the roots of an overturned tree.* This led to the discovery of the Biwabic, Cincinnati, Canton, Hale, and Kinawha Mines. During the winter of 1891 and 1892 test-pits were sunk in a number of places, leading to the discovery of many millions of tons of soft hæmatite ore within a hundred feet of the surface. The ore averages 63 per cent. of iron and 0·045 per cent. of phosphorus. The Biwabic is as yet the most important property, but the adjacent Cincinnati Mine is also of large size, and has been leased on

* *Iron Age*, vol. li. p. 63.

a guaranteed output of at least 150,000 tons per annum. On the property of the Kanawha and Hale Company the ore appears to lie in a kind of narrow gorge. For instance, of two test-pits sunk at a distance of 50 feet from each other, the one passes through 55 feet of ore, whilst the other is in green schist. This schist lies unconformably below the taconic rocks, and the ore is found in a depression between the two formations. The property known as the Mesabi Mountain has been leased on the basis of an annual output of 400,000 tons. In this and the Lone Jack properties, this pre-glacial gorge appears to have been excavated by a stream flowing in a westerly direction from the green schist ridge across the Lone Jack and Mesabi Mountain. This gorge then became filled with a kind of gravel consisting of round water-worn fragments of hard ore. The gorge was then covered with drift. At the bottom of this gravel-filled gorge is a stratified layer of light-coloured clayey matter, which varies in thickness from a few inches to 12 feet. Beneath this soft blue hæmatite is found.

Placing the cost of mining the ton of ore at 1s., and the royalty at 2s. 6d. per ton, the cost of the ton of ore delivered at Cleveland is a little over 12s. The contracts already made relate to an annual production of ore in this range of over one and a half million tons.

Iron Ore from the Vermilion Range.—Messrs. Pickands, Mather, & Co. give the following average analyses of the ore from various iron ore deposits in the Vermilion Range, which were mined in 1891 : *—

Description.	Vermilion.	Soudan.	Red Lake.	Minnesota.	Chandler.	Long Lake.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron	67·75	65·96	63·49	68·14	63·91	60·06
Silica . . .	1·58	2·27	5·00	1·30	5·10	7·20
Phosphorus . .	0·15	0·102	0·111	0·049	0·041	0·044
Manganese . .	0·29	0·14	0·19	trace	0·69	0·61
Alumina . . .	0·98	1·80	0·90	1·10	2·90	2·87
Sulphur . . .	trace	trace	0·026	trace	trace	0·043
Magnesia . . .	trace	0·30	0·30	0·13	trace	0·19
Lime . . .	1·00	0·54	0·71	0·56	0·37	0·31

The quantity of ore mined at the Chandler Mine in 1891 was 354,993 tons. The cost of mining and delivering at Cleveland is stated to be as follows :—

* *Iron Age*, vol. li. p. 17.

	Dollars.
Cost of mining	1·00
Royalty	0·35
Railway freight to Two Harbours	1·00
Lake freight to Cleveland	1·20
Insurance, commission, &c.	0·25
Total	3·80

Brown Iron Ore in Alabama.—The Baker Hill deposit of brown iron ore is, according to Mr. W. M. Brewer,* the largest in Alabama. It lies in Cherokee County, and forms a hill some 200 feet above the valley level. The ore often contains as much as 57 per cent. of iron, and the percentage of phosphorus, although too high for wheels, falls within the limit for coke iron. The ore body is mostly solid, but much gravel and clay containing ore is encountered. This material is accordingly treated in log-washers with revolving screens at the discharge. A perforated pipe in the axis of this screen completes the washing. The ore is washed out of the truck into the washer by a jet of water. About 65 per cent. of the ore does not require to be washed. Some seventy men are employed in getting the ore from open cuts on the hill-side and sending it down by self-acting inclines. A description of the various places and of the occurrence of the ore, together with an illustration, are given by the author.

The Iron Ores of Virginia.—The following are partial analyses of a number of representative samples of iron ore from various parts of Virginia, from the Blue Ridge to the Allegheny Mountains. Most of the ores are limonites :†—

No.	Iron.	Phosphorus.	Manganese.	Insoluble.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1.	46·67	0·58	1·69	14·43
2.	45·35	0·20	0·35	18·85
3.	48·21	0·41	0·16	14·12
4.	44·87	0·58	0·23	22·60
5.	42·78	0·76	0·14	24·32
6.	44·14	0·29	0·23	23·28
7.	46·79	0·27	0·48	18·09
8.	51·97	0·92	0·10	12·46
9.	46·33	0·32	0·64	19·93
10.	43·22	0·47	2·23	18·40
11.	51·34	0·37	trace	14·40
12.	48·36	0·03	trace	14·92

* *Engineering and Mining Journal*, vol. lv. pp. 77–78.
† *Iron Age*, vol. li. p. 375.

Iron Ore in Mexico.—The iron ore deposits of Mexico are reviewed by Mr. R. T. Hill* in the course of a discussion of the capabilities of that country as an iron-producer. At the present time, chiefly owing to difficulties of transport, the cost of even common castings is excessively high, but railways are now being built to a considerable extent. The Iron Mountain at Durango is one of the best known and largest of the many large deposits that have been discovered. The ore here consists of specular hæmatite and martite, and it averages 52 per cent. of metallic iron. Several other deposits have been studied by the author. Near Monclova, on the line of the Mexican International Railway, and three hundred miles nearer the coal supply, is one of the large deposits similar to that at Durango. It consists of an elongated mountain of hard blue limestone of Lower Cretaceous age, with enormous outcrops of ore some 1000 feet above the railway. Other similar deposits are found near Salome Botello, in the Sierra Carrissal, and also in the States on the Pacific coast. Ore has been smelted for several years near the coast in Catalan furnaces. Particulars of many of these deposits are given. In general, the deposits in the Northern States are in desert regions, where wood is scarce, but the southern State of Guerero is exceedingly well wooded. Several important coalfields have been discovered, notably that in Northern Coahuila, some sixty miles from Monclova and twenty miles from the Candeila ore. This coal is similar to that of the Rocky Mountain region. Anthracite is also reported on the Yaqui River of Sonora, and other coals are also mentioned. The probability of the use of Mexican iron ores is then discussed.

Iron Ore from Cuba.—Two analyses of Sigua iron ore, taken from a cargo consigned to America, have been published.† The results are as follows:—

Fe.	Cu.	S.	P.	Al_2O_3.	CaO.	MgO.	SiO_2.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
65·85	0·008	0·037	0·015	0·80	0·26	0·17	3·53
65·57	...	0·026	0·014	0·71	0·62	0·11	1·40

The furnace analyses showed 66·61 per cent. of iron and 0·010 per cent. of phosphorus. A second cargo, analysed by Mr. A. S. M'Creath, showed 63·35 per cent. of iron and 0·014 of phosphorus.

* *Engineering Magazine*, vol. iv. pp. 743–753, with map, and *American Journal of Science*, vol. xlv. pp. 111–119.

† *Iron Age*, vol. l. p. 1049.

Iron Ore in China.—The railway from Huangshihkang to the iron ore mine of Tiehshan has been completed. It is seventeen miles in length. The ore is found to average about 60 per cent. of iron, and occurs in such quantity that it has been used as the ballast for the railway. Limestone occurs in the immediate neighbourhood.*

Frondescent Hæmatite.—Mr. N. H. Winchell† describes a large specimen of dense hæmatite from the Vulcan Mine, similar to that described by Mr. W. S. Gresley.‡ Every feature Mr. Gresley described appears in this specimen, but in addition there is a larger number of the peculiar channels piercing the mass, and there is a further development of the radiating fibres, which, in their completion in frond-like growths, indicate the relation of these channels to the process of development. These channels were supposed by Mr. Gresley possibly to owe their existence to the removal of some object round which the hæmatite had grown; but it appears to the author that they date from the time of the development of the crystals, and are normal and natural.

Magnetite Pseudomorphous after Hæmatite.—Mr. A. J. Moses§ notes that in many specimens of iron ore from Antwerp, New York, the hæmatite has been reduced to magnetite near all surfaces on which either the silicate, stilpnomelane, and the ferrous carbonates, ankerite and siderite, have been deposited.

It has been considered doubtful whether the iron in the stilpnomelane is in the ferrous or ferric condition. The identity in condition of the associated iron oxide may suggest identity in the state of the iron in the stilpnomelane.

Löllingite from North Carolina.—Mr. F. A. Genth‖ has published the results of the analysis of some very pure fragments of löllingite from Drum's Farm, Alexander County, North Carolina. The results were as follows:—

Fe.	Cu.	As.	S.	Total.
70·83	trace	27·93	0·77	99·53

* *London and China Telegraph*, November 1, 1892.
† *The American Geologist*, vol. xi. pp. 20–21, two plates.
‡ *Journal of the Iron and Steel Institute*, 1892, No. II. p. 323.
§ *The School of Mines Quarterly*, vol. xiv. p. 52.
‖ *American Journal of Science*, vol. xliv. p. 384.

The specific gravity of the specimens was 7·031. No crystalline faces were exhibited, and the fracture was conchoidal.

The Solubility of Red Hæmatite.—C. Doelter * has conducted a lengthy series of investigations on the solubility of minerals. The various minerals selected were subjected in closed tubes to the action of various reagents for a long period at a temperature of 80° C. In the case of red hæmatite, it was found that after twenty-two days' treatment with water, 6·295 per cent. dissolved. After twenty-three days' treatment with a cold saturated solution of common salt, 2·74 per cent. dissolved, and after twenty-six days' treatment with a 10 per cent. solution of sodium carbonate, 1·987 per cent. dissolved. In these experiments 40 to 50 cubic centimetres of the solution were used for 0·5 to 1 gramme of the mineral.

Magnetite in Minerals and Rocks.—Professor A. Liversidge † has undertaken to solve the question as to the cause of the magnetic character of certain ores and rocks. The material was finely crushed in an agate mortar, and submitted to the action of a weak electro-magnet under water. The details of tests of fifty-five specimens from different localities are given, and show that the magnetic properties of chrome iron ore, franklinite, spinel, garnet, some hæmatites, and other minerals and rocks are due to the presence of included particles of magnetite. For example, a dark compact hæmatite from Elba yielded 15 per cent. of magnetite; franklinite from New Jersey yielded 32·23 per cent., and chromite from New Caledonia yielded 0·7 per cent. Pyrrhotine, however, appears to possess inherent magnetic properties.

Formation of Magnetic Oxide.—At the Sebastinaktiebolagets Chemical Works, Sweden, an interesting formation of mineral has been observed.‡ At this works the sodium bisulphate resulting as a by-product from the manufacture of nitric acid is heated with salt for the manufacture of hydrochloric acid. During the manufacture it was found that a cast iron appliance, made of metal containing 3·75 per cent. of carbon, began to be covered with scale, which finally attained considerable thickness, and on analysis proved to consist of—

FeS_2.	Fe_3O_4.	Fe_2O_3.	$FeSO_4$.	C.	SiO_2.
17·63	60·69	9·58	1·05	5·98	5·00

* *Tschermak's Mineralogische und Petrographische Mittheilungen*, vol. xi. p. 319.
† Paper read before the Australasian Association for the Advancement of Science.
‡ *Teknisk Tidskrift*, 1893, p. 62.

Mineralogical investigation showed the scale to be in the main a mixture of magnetite with pyrites.

Native Iron in Greenland.—It is stated by O. Nordenskiold * that the diamond-bearing meteoric iron of the Cañon Diablo † resembles some varieties of native iron found at Ovifak in Greenland. A piece of this in the author's possession weighs 88 lbs., and can neither be sawn nor cut. In the author's opinion, this depends on the presence of a number of black diamonds disseminated through the metal.

Recent Researches on Meteorites.—E. Cohen and E. Weinschenk ‡ have endeavoured to solve a number of problems connected with meteoric iron.

1. Cohenite seems to be confined to the Arva group. The composition of cohenite from the Magura meteoric iron is in accord with the formula $(FeNiCo)_3C$, whilst that of the carbide from the Wichita meteoric iron is in accord with the formula $(FeNiCo)_4C$.

2. The composition of schreibersite is in many cases constant, in that the ratio of Fe + Ni + Co to P is fixed; its formula being $(FeNiCo)_3P$. The new analyses of schreibersite from the Toluca, Glorieta Mountain, and Hraschina meteorites confirm this view.

3. The theory propounded by E. Cohen, that the hexahedral iron (kamazite) has a constant composition (about 7 per cent. Ni + Co) is supported by the analysis of the meteoric iron from the Hex River Mountains, Cape Colony. The mean composition of kamazite corresponds with the formula $Fe_{14}Ni$.

4. Two varieties of tænite occur in meteoric iron. One is tin-white, flexible, rich in Ni + Co, and contains no appreciable quantity of carbon. To this class belongs the tænite from the Toluca, the Wichita, and the Glorieta Mountain meteorites. The second variety presents a more greyish colour, less lustre, less flexibility, and less nickel and cobalt, whilst carbon is present in appreciable quantities. To this class belongs the tænite from the Staunton and Magura meteorites.

E. Cohen § publishes the following analyses of meteorites:—

* *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 677.
† *Journal of the Iron and Steel Institute*, 1892, No. II. p. 326.
‡ *Annalen des k.k. naturhistorischen Hofmuseums*, vol. vi. pp. 131–165.
§ *Ibid.*, vol. vii. pp. 143–162.

No.	Fe.	Ni.	Co.	Cu.	P.	C.	Insoluble.
	Per Cent.	Per Cent.	Per Cent.	Per Cent	Per Cent.	Per Cent.	Per Cent
I. . .	91·36	7·77	0·18	0·02	0·03	...	0·14
II. . .	91·18	7·63	0·66	0·01	0·03	...	0·49
III. . .	89·48	9·30	0·88	0·02	0·32	...	...
IV. . .	91·07	7·77	0·66	0·01	0·02	...	0·47
V. . .	87·88	10·40	0·72	...	0·92	0·08	...
VI. . .	37·24	62·01	0·72	0·28	0·15	...	...
VII. . .	81·54	17·74	1·26	...	0·11	...	0·05

I. From Schwetz an der Weichsel, Prussia; II. from Ivanpah, S. Bernardino County; III. Chupaderos, Mexico; IV. Misteca, Mexico; V. Glorieta Mountain; VI. Octibbeha County; VII. from Babbs Mill, Green County.

In those instances in which these meteorites had been already analysed the author gives the results that were previously obtained.

It is stated by E. Cohen * that copper, in small quantities, is of frequent occurrence in meteorites; but in five meteorites examined no arsenic, antimony, zinc, manganese, or chromium could be detected. The following are some analyses:—

Description.	Fe.	Ni.	Co.	Cu.	P.	C.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Glorieta . .	87·95	10·41	0·72	...	0·92	...
Chupaderos .	89·48	9·30	0·88	0·02	0·32	...
Toluca . .	90·70	8·41	0·61	0·01	0·27	...
Misteca . .	91·50	7·81	0·66	0·01	...	0·02
Wichita . .	89·36	8·62	0·72	0·02	0·97	0·31
Magura . .	92·91	6·46	0·82	0·01	0·32	0·30

C. Friedel † describes the occurrence of diamonds in the meteoric iron of the Cañon Diablo.‡ The specimen found by Mr. Eckley Coxe was cut in two, and a portion was treated successively with hydrochloric acid, aqua regia, and hydrofluoric acid. The residue contained minute rounded grains, which exhibited all the properties of the diamond. The diamonds were not uniformly distributed in the specimen examined, but were concentrated in and about nodules of iron sulphide and phosphide.

C. Friedel,§ in reference to the existence of the diamond in the meteoric iron from the Cañon Diablo, made an experiment in which some carbon bisulphide was enclosed in a small hollow in the centre of a steel block, which was then raised to redness. The carbon bisulphide was decom-

* *Annalen des k.k. Naturhistorischen Hofmuseums*, vol. vii. p. 101.
† *Comptes Rendus de l'Académie des Sciences*, vol. cxv. pp. 1037–1041.
‡ *Journal of the Iron and Steel Institute*, 1892, No. II. p. 126.
§ *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 224.

posed, and a small quantity of a black powder remained in the hollow of the block, which was so hard as to scratch corundum. This residue was a hard form of carbon.

According to Mr. E. J. Howell,* the third largest meteorite in the United States was found in November 1887 in the township of Mt. Joy, Pennsylvania. The three largest dimensions of the meteorite are 11, 24, and 33½ inches, and its weight is 847 lbs. Analysis yielded the following results :—

Fe.	Ni.	Co.	Cu.	P.	S.	Total.
93·80	4·81	0·51	0·005	0·19	0·01	99·325

The results of an examination of the magnetic properties shows that the meteorite as a whole acts as a mass of soft iron, gaining polarity under the inductive action of the earth.

According to Mr. H. L. Preston,† in August 1889 a meteorite was found in Kenton County, Kentucky, interlocked in the roots of an ash tree, 14 inches in diameter, at a depth of 3½ feet below the surface. It is a meteorite of the Siderite variety, measuring 21 by 14 by 8 inches in its greatest diameters, and weighing 359½ lbs. It has numerous shallow pittings and is entirely free from crust. On analysis it gave the following results :—

Fe.	Ni.	Co.	Cu.	C.	S.	P.	Total.
91·59	7·65	0·84	trace	0·12	trace	trace	100·20

Mr. W. G. Owens‡ states that a meteorite was found on September 25, 1891, upon the east side of Bald Eagle Mountain, Williamsport, Pennsylvania. It weighs 7 lbs. 1 oz., and resembles in general outline a human foot. It is pitted deeply, and is covered with a reddish-brown rust. Its specific gravity is 7·06. When polished, and etched with dilute acid, the Widmannstätten lines appeared very distinctly. Analysis gave the following results :—

Fe.	Ni.	Co.	P.	S.	Si.	Total.
91·36	7·56	0·70	0·09	0·06	trace	99·77

The meteorite could not have been of recent fall, as it was found covered with several feet of stones, and as far as can be learned it is the only specimen of the fall which has been found.

Mr. G. F. Kunz and Mr. E. Weinschenk§ state that in the spring of

* *American Journal of Science*, vol. xliv. pp. 415–416.
† *Ibid.*, vol. xliv. pp. 163–164.
‡ *Ibid.*, vol. xliii. pp. 423–424.
§ *Ibid.*, pp. 424–425.

1891 a mass of meteoric iron was turned up by a plough in Indian Valley township, Floyd County, Virginia. It weighs 31 lbs., and measures 11 by 8 by 5 inches. The surface is much corroded, and covered with a limonite crust. Analysis gave the following results:—

Fe.	Ni.	Co.	Cu.	P.	S.	Si.	Total.
93·59	5·56	0·53	trace	0·27	0·01	trace	99·96

The structure of this meteorite is very interesting, as it lies between the so-called breccia and hexahedral irons. Some parts of the mass exhibit a granular structure identical with that of the Chattooga meteoric iron. It is a question whether the granular structure is the original structure out of which hexahedral particles were formed through re-crystallisation, or whether it is due to the fact that this iron not being rich in nickel has a lack of crystallising power.

Mr. G. F. Kunz and Mr. E. Weinschenk * state that a meteorite was found in the Sierra de la Ternera, Province of Atacama, Chili. Although small, weighing but 650 grammes, it is undoubtedly the entire meteorite, as the unbroken original crust shows. Analysis gave the following results:—

Fe.	Ni.	Co.	P.	Total.
83·02	16·22	1·63	0·00	100·87

This analysis places the iron near the Cape Iron group; but as the physical properties of this group of irons have been so little studied, it is impossible to say whether the structure coincides or not. The complete absence of phosphorus indicates that this meteorite is an exception to the rule in not containing the characteristic phosphor-nickel iron.

Mr. J. R. Gregory † describes a portion of meteorite in his possession brought from Youndegin, from which place several masses have already been obtained and described by Mr. L. Fletcher.‡ This mass weighs 382½ lbs.

Professor G. H. F. Ulrich § describes a meteoric stone found in 1879 near Invercargill, New Zealand. The specific gravity of the stone varied from 3·31 to 3·54. The chemical composition is approximately as follows:—Nickel-iron, 1; oxides of nickel and iron, 10; troilite, 6; enstatite, 39; olivine, 44. The examination is not yet finished, and details will be communicated later. The microscopic examination proved the stone to belong to the chondrites or, according to Wadsworth, to the

* *American Journal of Science*, vol. xliii. pp. 425–426.

† *Nature*, vol. xlvii. pp. 90–92.

‡ *Journal of the Iron and Steel Institute*, 1887, No. II. p. 230.

§ *Proceedings of the Royal Society*, vol. liii. pp. 54–64, with six illustrations.

variety "Saxonite" of the peridotites, and to be composed of the following minerals:—Olivine, enstatite, glass, nickel-iron, troilite, and black opaque grains, probably magnetite.

P. Melikoff and C. Schwalbe * describe the meteorite that fell in November 1881 in the Grossliebenthal, near Odessa. It weighed over 17 lbs., and is covered with a black crust. The meteorite is finely granular, and of an ash-grey colour. It contains angular pieces of metal which are attracted by the magnet, and also fragments of iron sulphide and of iron chromite. It has a specific gravity of 3·584, and gave on analysis the following results:—

H_2O.	SiO_2.	MgO.	CuO.	FeO.	MnO.	Al_2O_3.	Na_2O.
0·10	39·57	22·97	2·28	13·44	0·53	2·45	1·30

K_2O.	Fe_7S_8.	$Fe_{11}N_2$.	$FeCr_2O_4$.	P.	P_2O_5.	Cl.	Total.
0·45	6·73	8·16	1·30	0·02	0·21	0·04	99·55

The total silicates amount to 82·99 per cent., and consist of olivine, bronzite, and albite.

Mr. H. A. Ward † gives a preliminary description of a new meteorite from Kesen, in Japan. It fell on June 13, 1850. The specimen examined is $6\frac{1}{16}$ oz. in weight, and its shape is that of an irregular triangle. The stone is eminently chondritic. The metallic portion forms 16 per cent. of the mass. This is an unusual percentage of metal—much more than in the Waconda meteorite, which the Japanese stone in some respects resembles. A fuller examination of the mineral constituents will shortly be made.

Mr. H. A. Newton ‡ describes some interesting markings on the ground and polished surface of a meteoric stone from Winnebago County. Subsequent examination revealed similar markings on other meteorites. The polished surface of the stone shows numerous bright metallic points arranged in lines in a manner suggestive of the Widmannstätten figures on metallic meteorites. These markings are such as might be expected if the forces which determine the crystallisation of the nickel-iron of the iron meteorites also dominated the structure of the rock-like masses of the stony meteorites, and the distribution in them of the iron particles.

S. Meunier § describes a meteoric iron from the desert of Saharah near Hassi Jekna, Algeria. It is a mass of iron weighing 1250 grammes, covered with a black crust of uniform thickness. When polished and

* *Berichte der deutschen chemischen Gesellschaft*, vol. xxv. pp. 234–241.
† *American Journal of Science*, vol. xlv. pp. 153–155.
‡ *Ibid.*, pp. 152–153.
§ *Comptes Rendus de l'Académie des Sciences*, vol. cxv. pp. 531–533.

etched with dilute acid, the surface showed well-marked Widmannstätten figures. The meteorite consists essentially of kamacite, plessite, lamellæ of schreibersite, and some troilite. Its specific gravity is 7·67, and its composition is as follows:—

Iron.	Nickel.	Cobalt.	Insoluble.
91·32	5·88	0·81	1·04

Traces of copper and sulphur were also observed. The meteorite is of the rare schwetzite type described by the author in 1870.

A meteoric body of an estimated weight of 20 tons fell in the vicinity of Jiminez, Chihuahua, Mexico, at the end of 1892, and is now in the Mexican Museum. In its fall this enormous body struck the side of a cliff, uncovering a rich vein of silver ore.*

Chrome Iron Ore in Lower Silesia.—B. Kosmann † describes the mode of occurrence of chrome iron ore at Tampadel in Lower Silesia. The ore is met with in veins, 23 feet in width, in serpentine, and contains inclusions of magnetite and spinel. Analysis gave results varying within the following limits:—

Chromic oxide	35 to 42
Magnesia	14 to 16
Silica	4 to 6
Ferrous oxide	18 to 22
Alumina	18 to 22

Manganese Ore in Wales.—Mr. E. Halse,‡ as addenda to a former paper§ on the occurrence of manganese ore near the Arenigs, Merionethshire, gives several analyses, including one complete analysis of an ore containing 48 per cent. of metallic manganese.

II.—*IRON ORE MINING.*

Iron Ore Mining in Cleveland.—After giving a short history of the discovery and development of iron ore in Cleveland, Mr. J. C. I'Anson‖ describes the drills used in this district. At the present time there are thirty-three Walker drills in use in the Cleveland mines. A

* *The American Geologist*, vol. i. p. 217.

† *Zeitschrift der deutschen geologischen Gesellschaft*, vol. xlii. pp. 794-796.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 167-168.

§ *Journal of the Iron and Steel Institute*, 1892, No. II. p. 329.

‖ *Engineering*, vol. liv. pp. 653-654; vol. lv. pp. 241-243.

skilled miner with hand drilling can get 4 to 6 tons of ore per shift, but one machine will get from 100 to 150 tons. Most of these machines are driven by compressed air, and they have enabled mines to be opened which would otherwise have laid idle. At the Liverton and Stangbow mines an endless belt receives the ore as it comes from the mines, and hand-picking on this belt is resorted to for cleaning the ore. Other forms of drills, designed by Steavenson and others, to be driven by electric or hydraulic power, or by petroleum engines, are also mentioned. Various other appliances in use at these mines are also described.

Cost of Working Iron Ore.—Mr. J. D. Kendall * gives full details of the cost of working iron ores in various localities. The figures he gives are rendered of permanent value by the addition of statements of the rate of wages and materials on which the costs are based.

In Cumberland and Furness, the miner's cost per ton of ore for working hæmatite deposits is stated to be—

	s.	d.
Hard compact ore	4	4·02
Loose rubbly ore	1	8·57
Furness softer ore	1	10·90

The total cost per ton in the first and second case, exclusive of royalty and way leaves, of putting the ores on to trucks at the pit's mouth, is given at 5s. 11·42d. and 3s. 9·65d. respectively. In both cases there is an output of 150 tons per day, and no water to pump.

Other examples of costs given by the author are as follows:—

	Total Cost per Ton on Ship or Train. s.	d.
Bilbao hæmatite	4	0·67
Antrim limonite	2	8·5
Southern Spain magnetite	4	11·0
Northampton (open-cast)	1	1·95
Similar ore worked by adits	2	1·94
Scotland, clayband ironstone	5	4·0

As many of the charges necessarily vary with the output, the examples given must only be considered as illustrative.

Iron Ore Mining in the United States.—Mr. J. Birkinbine † gives a series of plates to represent some of the methods of working the various kinds of iron ore deposits. The methods illustrated are—

* *The Iron Ores of Great Britain and Ireland*, London, 1893, p. 372.

† *Report on Mineral Industries in the United States at the Eleventh Census*, 1890, Washington, 1892.

(1) Brown hæmatite mining at New Birmingham, Texas; (2) brown hæmatite mining near Anniston, Alabama; (3) magnetite mining at Cornwall, Pennsylvania; (4) magnetite mining at Mineville, New York; (5) red hæmatite mining at Iron Mountain, Missouri; and (6) red hæmatite mining at Tower, Minnesota. Full descriptions accompany the illustrations.

Soft Ore Mining in the Lake Superior Region.—Mr. P. Larsson* describes the various methods in use for mining the ores known as soft ores in the Lake Superior district. These are the brown hæmatites and limonites of the Marquette range, the eastern ores in the Menominee range, all the Gogebic and Mesabi ores, and the Ely group of the Vermilion range. The methods are stripping and open pit work, rooming and timbering, filling and caving. Open work is used more or less in the whole of the district, although the depth is limited where the deposits dip above 45°. Steam shovels and locomotives are used for stripping. Probably it pays to strip the ore when its volume is equal to that of the barings. The second system of rooming with timbering is most extensively used. A common size is to make the rooms 20 to 24 feet wide, and the pillars somewhat less, with a length equal to the ore body. The rooms are worked from the bottom to the top of each lift, and are then filled with timbering. The system allows of a forced output, but the cost is heavy, and extensive cavings are likely to occur in large ore bodies. The cost is about one shilling per ton for timbering. Rock filling is sometimes preferable to timbering. It is most economical when shovelling is not required, that is, when the filling need not be close up to the bank of the slope. In the lower level of the Chapin mine this is done, as the ore will stand 20 feet wide over the whole width of the ore body. The system previously used at this mine of removing the ore in slices and filling up close to the back has been abandoned on account of the cost.

Two methods of caving are used. In one, stoping is commenced at the top of the lift under a gob roof; in the other, working is begun at the bottom under a soft roof of ore, which keeps coming down. The former method is largely used in Europe, especially in the North of England. The latter method was adopted eighteen months ago at the Chapin mine. A comparison is then given of the circumstances under which these two systems are most advantageously employed. In the

* Paper read before the Lake Superior Mining Institute; *Engineering and Mining Journal*, vol. lv. p. 318.

first system there is no danger of leaving offshoots, while in flat or irregular deposits short lifts should be taken in the Chapin system. At the Chandler mine the lift is mined from above in floors 15 feet thick. Other applications are in use at the Norrie and Lake Angeline mines. Some discussion ensued, and reference was made to the system of filling at the Minnesota mine described by Mr. D. H. Bacon.*

The Chapin Iron Ore Mine.—A sketch of the underground haulage systems at the Chapin iron mine, Houghton, Michigan, is given by Professor W. J. Baldwin.† At this mine the ore is of medium hardness, sometimes requiring blasting. The ore body is over 70 feet wide, and the ore, as it is mined, is thrown into vertical openings which deliver it through shoots to the trucks. These can be loaded on both sides of the level, and cross-over switches connect the two trucks every 200 or 300 feet to transfer the loaded trucks to one line. There are several levels from which ore is wound through three shafts, the B, C, and D, of which the latter was sunk by the freezing process. About 2000 tons are raised daily. The haulage engines are placed on the surface, and drive three haulage systems, with a total length of rope of 14,000 feet. The rope-driving drums have three grooves, and the idle drums two grooves. The ropes are led round tightening pulleys in a trench, and to throw one out of gear the tension weight is raised, and the rope is thrown off its pulleys. A description of the guide pulleys and sheaves is then given by the author.

The trucks are run singly, each having a gripping device fixed on its end. This consists of one vertical fixed jaw and a laterally swinging jaw, which is moved by an adjustable toggle worked through a link from a lever projecting at the side of the truck. Detaching is done automatically by a curved bar fixed at the side of the line to depress the projecting lever. The caging device is inconvenient, as the empty trucks are not pushed through the cage, but come out on the same side as the loaded ones enter. The speed of the endless rope is very slow, being only 105 feet per minute, the trucks are put on 50 to 60 feet apart, and the life of the rope is only ten months, working two shifts of ten hours daily.

Electric Percussive Rock Drills.—The general requirements for an electric percussive rock drill, according to Mr. H. N. Marvin,‡ are

* *Journal of the Iron and Steel Institute*, 1892, No. II. p. 334.

† *Journal of the Illinois Mining Engineers*, vol. i. pp. 154–163, with four plates.

‡ *Transactions of the American Institute of Electrical Engineers*, vol. ix. pp. 407–424, with illustrations.

that it shall be light enough to be easily handled, powerful enough to compete with compressed air-drills, simple in design, so that it can be repaired by an ordinary mechanic without electrical experience, capable of being soaked in mud or water without injury, and of enduring rough handling, and that it shall be incapable of burning out. The following elements of construction should, in the author's opinion, be avoided:—Travelling conductors, commutating or current shifting devices, sliding and spring contacts, cotton or other insulation liable to carbonisation, switches, lamination of the moving parts, close fittings, and joints liable to be impaired by wear.

The solenoid and plunger affords the simplest solution of the problem, and four methods of utilising these are discussed. In 1888 the author devised his system of working, in which two coils with three leads are used, and the coils are excited alternately. The number of times the coils are excited, and accordingly the number of blows of the drill, depends on the number of revolutions of the armature in the dynamo. Several plans for running the dynamo at a proper speed, of reducing the number of pulsations, and of taking the requisite current are described. The second plan is that of Van Depoele, and depends on a difference of phase in the two coils, three leads being also used. The third plan is that of Siemens and Halske, in which three coils are used. The centre coil is excited by a continuous current, and the outer ones by alternating currents of proper frequency. Four leads have to be used, but Van Depoele reduced these to three by the use of a rotating armature to send an alternating current through the end coils, and a unidirectional pulsating current of half the frequency through the centre coil.

Turning now to the construction of the drill itself, three types have been built, and of these illustrations are given. The first of these was worked in May 1891. In the latest form, the plunger is a solid steel forging, 4 inches in diameter, without the brass parts used in previous drills. The construction of the rotating gear and of the other parts follows generally that of the compressed air-drill. By means of a rotating drum and tracing pencil like a steam engine indicator, curves have been taken during the stroke of the drill to investigate the motion. These curves are discussed, and are compared with voltage curves in the coil.

Electric Rock Blasting.—Mr. W. L. Saunders * describes at some length the various appliances used for electric blasting in America. The

* *Transactions of the American Society of Civil Engineers*, vol. xxvii. pp. 529-564.

disposition of the holes and the strength of the detonator are referred to together with the conductors, and means for joining, insulating, waterproofing, and laying them. Uniformity of the fuzes is insisted upon. For generating the current small magneto-electric machines are used, and several forms of these are described. In the latest form of these machines the armature is revolved by gearing operated on the release of a spring which is first compressed by the workman. The use of testing apparatus for finding if the circuit is complete, by means of a small current, is condemned as practically useless by the author. Tamping is briefly mentioned, water tamping being objected to. It is not advisable to use the electric light current for blasting, but Mr. J. A. Van Mater has employed it with success by inserting five incandescent lamps in the circuit as a resistance. The question of removing the rock is gone into, steam shovels and wire-rope hoists being mentioned, and some details are given of the cost and of the quantity mined at the Croton Magnetic Iron Mines for the last half of 1892.

III.—*MECHANICAL PREPARATION.*

Concentration of Irish Iron Ores.—Mr. W. J. May * gives the results of some experiments made to determine whether Irish aluminous ores were capable of being concentrated. Four samples were tested, and it was found that, by crushing and washing, the iron contents could be increased, but that magnetic concentration was not available, as most of the ores were not magnetic to any extent either before or after roasting. One sample gave :—

	Iron.	Insoluble Matter.
	Per Cent.	Per Cent.
Crude ore	41·5	19·05
Ore crushed to pass 25 millimetre sieve . .	52·73	15·03
„ „ 5 „ . . .	55·61	9·16

The Separation of Iron Carbonate from Zinc Blende.—J. Billek † describes an application of electro-magnetic machines in the separation of an intimate mixture of iron carbonate and zinc blende. The iron carbonate contained more or less magnesium carbonate, but it was not thought necessary to prove the lowest limit for iron in such a

* *Colliery Guardian*, vol. lxiv. p. 1205.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 39–44 and 51–57, with two plates.

mineral that would admit of the application after roasting of electro-magnetic separation. One analysis showed this mineral to contain :—

$FeCO_3$.	$MnCO_3$.	$CaCO_3$.	$MgCO_3$.	ZnS.	Insoluble.
79·65	1·28	2·36	13·80	0·71	2·12

By mechanical separation it was found impossible to effect a separation of the zinc blende with which this mineral was associated. In the process now adopted this material is roasted in shaft-kilns of rectangular shape, 3 feet 3 inches wide, 6 feet 6 inches long, and 10 feet 8 inches in height, with a knife-edge bottom, sloping at an angle of 45° to the two withdrawing openings. It was found, however, that this furnace showed a tendency in working to become clogged by slag adhering to its walls. This difficulty was overcome by building a narrow dividing wall up the centre of the kiln, dividing it into halves, for a distance of about 3 feet from the bottom. The outturn of such a kiln is about 7½ tons a day. The roasted material is powdered, and subjected to the action of the magnetic separators. The degree of success attained is shown in the following table :—

Description.	Zinc.	Iron.
	Per Cent.	Per Cent.
50·5 tons original material . . .	28·4	14·2
37·3 ,, separated zinc ore . . .	34·0	9·8
13·2 ,, separated iron ore . . .	18·5	23·7
85·4 ,, original material . . .	25·8	19·8
48·4 ,, separated zinc ore . . .	34·9	10·0
37·0 ,, separated iron ore . .	14·5	33·5

Magnetic Separation.—In describing magnetic separation, Mr. H. S. Chase * says that more rapid work can be done dry, but cleaner and more perfect work wet. The repairs and renewals in the wet process are less, as the water acts as a lubricant and a cleaning medium.

Shipping Iron Ore.—Mr. J. Birkinbine † gives an account, with illustrations, of some of the larger docks in the United States, used for shipping and unloading iron ore. There are six shipping ports for the Lake Superior district, the most important being Escanaba, on Lake Michigan, where there are four docks. The railways in these docks are

* *Technology Quarterly*, vol. v. pp. 64–69.

† *Report of the Mineral Industries in the United States at the Eleventh Census*, 1890, Washington, 1892, pp. 26–29, with seven plates.

elevated from 35 to 47·5 feet above water level, and the ore is discharged from the trucks through drop-bottoms into pockets, from which it is loaded into the vessels through shoots. From the particulars given, it appears that the length of the docks varies from 600 to 1500 feet; the number of pockets in a dock from 78 to 250, and their capacity from 4000 to 33,000 tons. Illustrations are also given of the receiving docks, the largest of which is at Fairport, Ohio, with a frontage of 1 mile, and a width of 180 to 350 feet. The ore is stored to a height of 25 to 50 feet. About one-third of the ore is loaded direct on to the wagons during the shipping season, which lasts seven months, and the rest is stored. There are five general types of equipment of machinery at these docks for unloading the vessels.

REFRACTORY MATERIALS.

The Fire-Clays of Alabama.—Dr. E. A. Smith * classes the fire-clays of Alabama under five heads according to their geological position. Clays of the crystalline schists or metamorphic formation are found in Coosa, Cleburne, and Randolf Counties. Cambrian and Silurian clays include the bauxites and kaolins of Cherokee and Calhoun Counties. Subcarboniferous clays occur at the base of the formation in close proximity to the underlying black shales. They approximate to halloysite, and have been worked in De Kalb County. The fourth class, or Cretaceous clays, are widely distributed in the Tuscaloosa formation over a large part of the state, an analysis of one specimen from Marion County being given below. Clays of the Tertiary formation occur in the Buhrstone division of the state in Choctaw County. The results of analyses of several samples are as follows :—

Locality.	Silica.	Alumina.	Oxide of Iron.	Potash, Lime, Magnesia, &c.	Water.	Undecomposed Material.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Louina, Randolf County . .	37·29	31·92	trace	0·72	15·09	14·28
Jacksonville, Calhoun County	44·60	38·92	0·78	1·03	13·88	0·90
Chalk Bluff, Marion County	47·20	37·76	0·91	traces	14·24	...
Choctaw County	36·30	45·12	1·60	0·46	6·60	...

The great variety of the clays and their wide distribution offer a large field for selection.

Bauxite.—Bauxite was first discovered in 1821 in France, but, according to Mr. H. M'Calley,† did not come into commercial use until 1868. It occurs in Ireland, Austria, Asia Minor, and in the United States in Georgia, Alabama, Arkansas, and North Carolina. In Georgia the deposits only cover a small area of unknown depth. In Arkansas

* *Proceedings of the Alabama Industrial and Scientific Society*, vol. ii. pp. 33–42.
† *Ibid.*, pp. 20–32.

it is stated that they cover about 160 acres to an average depth of 15 feet. In Alabama it was first discovered in 1887, and it there occurs in several localities. So far as is known, the deposits are of Silurian age. The district is greatly disturbed, and the mineral is found mostly in pockets associated with limonite and clay. In Cherokee County, bauxite is found along two lines of outcrop which are 150 to 200 yards apart, following the crests of two anticlinal folds. In places it overlies a white or yellow sandstone, and underlies an unctuous clay which carries brown iron ore in the upper part. In the north-east end of the Dikes' brown ore bank, the bauxite forms an irregular seam about 60 feet in thickness, and has been developed to 75 feet in depth in one place where it lies vertically, but the dip is variable, as is also the thickness. Several of the localities where it is worked are described, and the following given as an average analysis of the mineral from Cherokee County :—

Alumina.	Oxide of Iron.	Insoluble Siliceous Matter.	Titanic Anhydride.	Water.
56 to 60	2·75	7·0	2 to 3	25 to 30

A further reference is made * to an extensive deposit known as the Washer, which has recently been opened in this district.

Dr. E. Przìwoznik † gives the following results of an analysis of bauxite, of a jasper-like character, from the mines of the Austrian Alpine Company :—

Ferric oxide	14·85
Alumina	66·05
Manganese	trace
Copper	0·01
Lime	1·30
Magnesia	0·29
Silica	5·10
Phosphoric anhydride	0·02
Sulphuric anhydride	0·38
Loss on ignition	12·10
Total	100·10

Analyses of Dolomite.—The following are analyses of some varieties of dolomite used in the lining of basic Bessemer converters : ‡—

* *Engineering and Mining Journal*, vol. liv. p. 581.
† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. p. 464.
‡ *Stahl und Eisen*, vol. xiii. p. 104.

Locality.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	CO_2.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Near Metz	3·20	0·21	1·79	35·65	15·97	43·18
Huddlestone	0·45	...	0·47	30·82	21·37	46·75
Kiverton Park	3·99	0·37	1·65	29·12	20·96	43·60
Grevenmacher	1·20	2·00	...	29·00	20·00	47·00
Beffort	3·50	4·00	...	29·00	18·99	43·00
Varigny	4·10	3·00	1·70	28·30	18·60	44·20
Dombrowa	2·00	1·30	3·20	31·00	16·00	45·40

The Grevenmacher Luxemburg dolomite is used at the basic Bessemer Steelworks of Hayingen, Longwy, and Düdelingen, and after burning has the composition :—

SiO_2.	Al_2O_3.	CaO.	MgO.
2·0 to 3·0	3·0 to 6·0	56·0 to 57·0	37·0

A dolomite suitable for use in the lining of basic open-hearth furnaces is found near Karánsebes, Örményes, Hungary. It has the composition shown by the following analysis, an analysis of the burnt material being also given : *—

	Raw.	Burnt.
	Per Cent.	Per Cent.
Silica	1·54	0·70
Alumina	1·28	0·22
Ferric oxide		2·58
Lime	...	57·75
Magnesia	...	37·82
Carbonic anhydride	...	0·93
Calcium carbonate	52·50	...
Magnesium carbonate	44·10	...
Totals	99·42	100·00

The Styrian Deposits of Magnesite.—Professor Wedding † observes that magnesite deposits occur at the foot of the Semmering, and that they extend to the neighbourhood of Veitsch in Styria, where the deposit reaches its greatest development. The formation is Silurian, consisting of argillaceous shales, quartzite, dolomite, and limestone, which in turn rest upon gneiss. The magnesite, which is rarely pure, conforms with the strata. It is usually seamed with small stringers of limestone, dolomite, and quartz, with occasional segregations of dolomite crystals. Cobbing is therefore necessary. The picked magnesite is next calcined,

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 20.
† *Stahl und Eisen*, vol. xiii. pp. 279–286.

the plant usually admitting of a daily outturn of 80 tons of sintered magnesite. To produce this in its best quality a very strong white heat is required. In order to prevent the introduction of impurities the portion of the furnace where the highest temperature is attained is lined with magnesia bricks. The quantities of iron oxide and silica that the magnesia contains are so small that they do not lead to the formation of slag, only producing a sintering action. The furnaces are continuous, the calcined sintered magnesite being drawn every six hours. It is delivered to a mechanical sorting plant, where the dust is removed, and where particles of quartz and of other impurities are picked out by hand. The removal of the dust leads to a considerable reduction in the percentage of the lime, as this slacks readily and forms a powder which is easily removed. The remainder of the sintered material is then crushed and formed into bricks under a hydraulic press working at a pressure of 300 atmospheres. The bricks so made are dried and burnt in quantities of from 3000 to 6000 at a time in calcining chambers, nine of which constitute a plant. These chambers are also lined with magnesia bricks. For special purposes, such as for crucibles, tuyeres, &c., doubly calcined magnesite is used, and occasionally even articles so made are reburned two or three times. The moulds in which the bricks are made under the press are of the hardest steel, and even these are worn out with remarkable rapidity. In 1892 the quantity of raw magnesite exported from this district was 3700 tons, and that of the sintered material and of manufactured products about 9000 tons, including 600 tons of magnesia bricks. The yield of sintered magnesia from the raw material is about 50 per cent. An average analysis of this material gave results as follows :—

MgO.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.
85·34	3·40	0·82	7·70	1·70

The lower the percentage of lime contained in magnesia, the less readily does it enter into combination with silica. Indeed it is possible to build Dinas bricks directly on a basic magnesia hearth.

In making a basic hearth of magnesia, finely ground sintered magnesia is mixed with five parts by weight of clean basic open-hearth slag, containing—

SiO_2.	Al_2O_3.	CaO.
10·0 to 15·0	2·5 to 3·5	18·0 to 30·0

Some works use hammer or roll scale in place of this slag. Inclusive of the materials used in building the furnace, the consumption of magnesite per ton of steel made is from 30 to 40 lbs., from 100 to 200 lbs. being

used for repairs in each heat. It is stated that a well-rammed magnesia hearth will often outlast three Dinas roofs. Again, the hearth may be built up of magnesia bricks, but these bricks must be of special shape to reduce the quantity of binding material or mortar to a minimum. This mortar consists of finely powdered slag from the furnace mixed with magnesia. It is not desirable to build in the material by itself, as the specifically lighter magnesia would rise up through the bath of metal. An inverted arch should be the arrangement adopted in all such constructions. "Milk" of dolomite is sometimes used instead of tar in binding the ground magnesia, but its use is not always successful.

Magnesia Bricks.—Dr. C. Bischof * gives the following analyses of magnesite used in the manufacture of magnesia bricks :—

	Styrian.	Greek.
	Per Cent.	Per Cent.
Magnesium carbonate . .	90·0 to 96·0	94·46
Calcium carbonate . . .	0·5 to 2·0	4·40
Ferrous carbonate . . .	3·0 to 6·0	Fe_2O_3 0·08
Silica	0·0 to 1·0	0·52
Manganic oxide	0·0 to 0·5	H_2O 0·54

Samples of these materials when burnt were found to contain :—

	Styrian.	Greek.
	Per Cent.	Per Cent.
Magnesia	77·6	82·46 to 95·36
Lime	7·3	0·83 to 10·92
Silica	1·2	0·73 to 7·98
Ferric oxide and alumina . .	13·0	0·56 to 3·54

The Styrian magnesite was from the valley of the Veitsch, and the Greek from Mandondi, on the island of Eubœa. The Styrian magnesite is considered better suited for the manufacture of brick than is the Greek variety. It possesses in a marked degree the property of "sintering" or clotting together when heated to very high temperatures without actually fusing. In doing so its colour changes to a deep brown, or even to a blue black. This sintering action is apparently connected with the presence of iron and alumina. Various types of furnace, both kiln and reverberatory, are employed, lined with highly siliceous material, or with magnesia bricks themselves. The author describes a highly heated

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 27-30.

gas furnace. By repeated burning at very high temperature the magnesite diminishes in bulk to the extent of 25 per cent. on the original length of the piece of magnesite. If this burnt material is crushed a sandy mass is obtained, which requires some binding material if it is to be converted into bricks. When magnesite or magnesia hydrate is raised to a high temperature, there is formed at a dull red heat a magnesia which can be worked into shape at high pressures, being of a more or less binding character, and possessing marked hydraulic properties. If heated still higher this magnesia diminishes largely in bulk, becomes hard, and altogether unmouldable. The specific gravity of dead-burnt magnesia rises from 3·0 to as much as 3·8. The presence of a small quantity of iron oxide and alumina becomes of the utmost importance in connection with the sintering of the mass on heating. As binding materials when converting the magnesia into bricks various substances have been employed. In some instances 15 per cent. or more of clay has been used, and especially anhydrous tar, soda, silica, vinegar, phenolates, and numerous other materials have also been suggested. The addition of clay influences the infusibility of the magnesia, and those other materials which contain volatile components influence the firmness of the burnt material. Use is made of magnesium chloride as a binding material and also of the property possessed by magnesia burnt at a low temperature, to which reference was made above. As much as 10 per cent. of this caustic magnesia is employed. When this caustic magnesia is used for stamping purposes and as a mortar, it is customary to add a little silica to it to slightly lower the melting-point. If it is a question of producing a very firm compact material a little iron oxide or even some silicate is added. In shaping the bricks high pressure must be used, and to prevent cracking the drying should be performed very slowly. Before burning, the bricks must be perfectly dry, and the burning must be effected evenly and at a high temperature; the cooling must be effected at as slow a rate as possible. Above all, the magnesite must be carefully selected, and then burnt in such a manner as to produce both a binding and a sintered material. The author recommends the use of reverberatory furnaces, or of the Mendesheim gas furnace for burning the bricks, and then proceeds to describe the method of manufacture that was adopted at the works at Brieg in Silesia, the ownership of which has recently changed hands, and the manufacture there of magnesia bricks ceased. The raw material employed was the magnesite found near Frankenstein. A portion of this to be used as a binding material was burned at a low temperature, while the remainder was sintered at as high a temperature

as possible. The burnt magnesite was crushed by rollers and sifted. To the fine powder a little magnesium chloride was added, and the mass was then pressed into bricks in a hydraulic press working with a pressure of 110 atmospheres, the pressure exerted upon each brick amounting to about 50 tons. The pressed bricks were carefully dried in the air, during which process they heat up slightly and become more dense and compact. After about a week they were burnt. The furnace used was the Mendesheim gas furnace, one of the circular or ring-shaped chamber ovens. The bed of this furnace was lined with magnesia bricks. A very high temperature was attained in this furnace, a mixture of felspar and clay being used for pyrometric purposes. The bricks produced had the composition—

MgO.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.
80·9	4·8	1·6	6·8	6·5

As to the relative cost of manufacture of these bricks when compared with that of ordinary fire-bricks, it is found that the magnesia bricks are much the more expensive of the two. The raw material is dearer, the necessary preliminary operations are more difficult, and the high temperature needed for burning the bricks cannot be attained without extra expense. A magnesia brick will only stand contact with clay up to a temperature of about 1600° C. If the temperature exceeds this, it will be found that a piece of magnesia brick placed upon a clay slab will melt down to a grey thin fluid mass which will pierce the clay slab on which it rested. If, instead of clay, pure alumina was used, then the magnesia stands somewhat better, though not to any very great extent. If, however, the burnt magnesia lump is placed on coke or gas-retort carbon, it may be heated almost to the melting-point of platinum without fusing, and some of this material from Veitsch in Styria has shown sharp edges even when raised above the melting-point of that metal. Pure magnesia stands this temperature readily, provided always that there is nothing else present with which, in its character of a base, it can enter into combination.

Hungarian Chrome Iron Ore.—W. Sóltz * publishes the following analysis of a chrome iron ore found in considerable quantity in the neighbourhood of Orsova, Hungary :—

Cr_2O_3.	FeO.	SiO_2.	Al_2O_3.	CaO.	MgO.
38·95	17·13	8·00	17·50	2·20	17·20

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 19.

He adds that it is remarkable that in open-hearths lined with chrome iron ore, scarcely any chromium passes into the resulting ingot metal.

Standard Size for Fire-Bricks.—At the general meeting of the Society of German Manufacturers of Refractory Products, held on March 1, 1893, it was decided to adopt 250 by 123 by 70 millimetres (9·84 by 4·84 by 2·78 inches) as the standard size for fire-bricks.*

A Regenerative Kiln.—A regenerative kiln, designed by Mr. F. C. Roberts, is illustrated in the *Iron Age*.† The plant actually illustrated is not arranged for fire-brick manufacture, but it consists of three kilns operated by one set of regenerative chambers in which the air is pre-heated. The arrangement of the plant is described in detail. Taylor gas producers are employed, burning anthracite pea coal.

* *Mittheilungen über Gegenstände des Artillerie- und Genieweseus*, 1893, p. 353.
† Vol. l. p. 1219, two illustrations.

FUEL.

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I.—*CALORIFIC VALUE.*

Calorific Value of Coal.—C. von John and H. Baron von Fullon * have made a series of assays of fuel by the Berthier method in the laboratory of the Austrian Geological Survey. Although the results obtained by this method are not of scientific value, they are, in the author's opinion, of practical use in indicating the quality of a coal when other data are not available. The following table gives the calorific power calculated from the elementary analysis of the fuel, and obtained experimentally by Berthier's method.

No.	H_2O.	Ash.	C.	H.	N+O.	S.	Calories.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Calculated.	Berthier's.
1.	3·50	21·50	72·46	0·80	1·51	0·23	6069	6045
2.	22·35	5·15	59·11	4·23	8·24	0·92	5717	5269
3.	10·58	6·42	64·09	5·09	11·33	2·49	6352	5851
4.	8·70	2·76	67·01	4·29	17·24	...	6026	5669
5.	6·34	10·98	69·27	4·02	8·42	0·97	6522	6113
6.	7·54	10·08	67·12	4·83	10·51	0·92	6163	5892
7.	10·65	9·84	66·13	3·65	8·70	1·03	6046	5796
8.	20·40	3·95	52·06	4·12	18·03	1·44	4593	4171
9.	18·65	5·35	51·27	4·08	19·40	1·25	4463	4072
10.	3·00	16·16	45·27	3·90	21·67	...	3811	3318
11.	1·50	13·12	62·07	4·51	18·74	...	5711	5374
12.	19·50	2·36	56·61	4·19	17·34	...	5035	4617
13.	19·18	7·74	52·91	4·10	13·96	2·11	4918	4597
14.	27·32	3·74	48·42	3·69	14·36	2·47	4353	4323
15.	25·80	3·85	53·73	4·30	12·24	0·08	5104	4860
16.	25·50	2·70	54·36	4·52	12·89	0·03	5204	5049
17.	11·90	25·50	48·35	3·23	10·06	0·96	4635	4298
18.	11·64	17·20	48·60	4·19	14·06	4·31	4626	3485
19.	9·44	39·09	33·31	3·33	12·68	4·15	3006	2146
20.	33·30	4·74	47·62	2·56	9·02	2·76	4000	3155
21.	25·38	17·70	37·12	2·83	13·31	3·66	3158	2895
22.	26·90	14·04	43·54	2·52	10·22	2·78	3703	2927
23.	17·76	6·32	50·68	3·96	17·77	3·51	4534	4416
24.	21·35	8·95	47·30	4·61	15·14	2·65	4515	3844

1. Anthracite from Orselia, near Genoa; 2. Trzebinia (lower carboniferous); 3. Temesinek, Galicia (Schatzlar beds); 4. Buschtehrad; 5. Washed smalls from the same

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlii. p. 155.

colliery; 6 and 7. Kladno (Radnitz beds); 8 and 9. Trifail; 10 and 11. Briquettes (Sotzka beds); 12. Brüx, Theresia shaft; 13. Victoria shaft; 14. Dux, Theodor shaft; 15. Türmitz, Albert shaft; 16. Elisabeth shaft (Neogene); 17. Porstendorf, Moravia; 18. Sajo Kaza, coal; 19. Briquettes; 20. Tregist; 21. Trifail, bog coal; 22. Lignite (Pliocene); 23. Gotschee; 24. Grudno, Galicia (Miocene).

H. Bunte * observes that M. Scheurer-Kestner, disputing the value of the Dulong formula for the calculation of the calorific power of fuel, lays stress on a coal from Bascoup that he and M. Mahler had examined calorimetrically. The author considered that the elementary composition of this coal, given by Scheurer-Kestner, was probably inaccurate, and by analysis this belief was found to be true. This coal, too, is found to be in strict accordance with the Dulong formula, the calculation giving a calorific power of 8760 calories, whilst the actual calorimetric determination showed 8820 calories, a difference of only 60 calories, or 0·7 per cent. The Bascoup coal contains :—

Carbon.	Hydrogen.	O+N+S.
92·19	4·24	3·57

Calorific Value of Wood.—Taking the calorific value of the lime or linden tree as unity, O. Petit has found that of other woods to be as follows :—Fir, 0·99; Scotch fir, elm, and aspen, 0·98; willow, horse-chestnut, and larch, 0·97; maple, 0·96; black poplar, 0·95; alder, birch, and oak, 0·94; ash, 0·92; acacia and hornbeam, 0·94; and beech, 0·99. It is thus seen that the calorific value of soft woods is equal to or greater than that of hard woods.† Some investigations have recently been made by Reszoff ‡ on the value of straw as fuel. Several kinds of straw are dealt with, and their calorific value, as determined by Dulong's formula, ranges from 3090 to 3724 for flax straw dried at 110° C.

The Combustion of Carbon in Air.—R. Ernst § points out that the published statements differ greatly as to whether carbon burns in the first instance to carbonic oxide or to carbonic anhydride. Experiments that he instituted showed that the formation of carbonic anhydride begins at about 400°, at which temperature small quantities of carbonic oxide are also formed. The rapidity of formation of the carbonic anhydride goes on increasing until the temperature of 700° is reached, when it attains a maximum. This temperature exceeded, its formation

* *Dingler's Polytechnisches Journal*, vol. cclxxxv. p. 183.

† *Colliery Guardian*, vol. lxv. p. 529.

‡ *Journal of the Russian Technological Society; Dingler's Polytechnisches Journal*, vol. lxxiii. pp. 260-263.

§ *Chemisches Repertorium*, vol. xvii. p. 2.

gradually lessens, more and more carbonic oxide and less carbonic anhydride being formed, until at the temperature of 995° C., and at still higher temperatures, only carbonic oxide is formed and no carbonic anhydride. This explains the combustion of charcoal without flame at a temperature of 700°, while at 1000° a flame becomes visible.

The Temperature of the Electric Arc.—J. Violle * has again determined the temperature of the electric arc. This he places at 3500° C., or that at which carbon volatilises. The quantity of heat which is required to bring one gramme of graphite to the point at which it volatilises is 1600 calories, and Weber and Dewar have shown that 300 calories are required to raise it from 0° to 1000° C. This the author employed as the basis for his determination, the most heated portion of the positive carbon being broken off, and allowed to fall into a calorimeter designed especially for the purpose.

H. Moissan † describes an electrical furnace in which by the use of a 50 h.p. engine, giving a current of 450 ampères and 70 volts, a temperature of about 3000° C. can be obtained. When using this furnace, it was found that at about 2250° Cr_2O_3 and Fe_3O_4 melt rapidly; lime, strontia, and magnesia crystallise in a few minutes at 2500°, and the oxides of nickel, cobalt, manganese, and chromium are rapidly reduced by the carbon pole of the furnace at this temperature. As the temperature approached 3000° the oxide of uranium was reduced to the metallic form, 120 grammes of the metal being made in ten minutes. At this temperature, too, the lime of which the furnace was composed began to melt down rapidly.

The author states that using an electric furnace, pure alumina melts at 2250° and then crystallises. By the addition of small quantities of chromic oxide, small crystals of ruby resulted. Ferric oxide fuses rapidly, yielding partly fluid and in part crystallised magnetic oxide. Both ferric and chromic oxides yield fusible compounds with lime under these conditions, which crystallise well. The oxides of nickel and cobalt are readily fused; titanic anhydride yields black crystals of the lower oxide, which is rapidly volatilised, as also are both boric acid and alumina.

Pyrometry.—Mr. G. C. Farkell and Mr. H. G. Hamman ‡ discuss the determination of temperature by the change in the electrical resist-

* *Comptes Rendus de l'Académie des Sciences*, vol. cxv. p. 1273.
† *Ibid.*, vol. cxv. pp. 1031-1034.
‡ *The Sibley Journal of Engineering*, vol. vii. pp. 53-57.

ance of conductors, and give some experiments of their own on this subject, made with spirals of iron wire enclosed in a porcelain envelope.

A description of the Wiborgh air pyrometer is given by Mr. E. Trotz,* together with the methods of using it for temperatures between 0° and 2400° F.

II.—*COAL.*

The Soluble and Resinoid Constituents of Coal.—In continuation of their previous researches,† Professor W. Smith and Mr. J. C. Chorley ‡ give further details of the resinoid constituents of the Miike coal from Japan. The benzine extract was fractionally distilled and the distillates investigated. The lower distillate contained some aromatic hydrocarbons, and the higher ones some nitrogen bases resembling pyridine and quinoline in odour. The various products that are isolated show that coal undergoes a slow and gradual destructive distillation; the resins found are not the original unaltered resins of the vegetation, but are alteration products mixed with other matters. The distilled portions are similar to various natural petroleums.

Vanadium in Lignite.—Mr. J. J. Kyle§ publishes a description of a lignite of which a bed has recently been discovered in the neighbourhood of the town of San Raphael, in the province of Mendoza, Argentine Republic. The lignite is black and lustrous, and somewhat fragile. On heating it softens, burns with a smoky flame, and yields a porous coke. On this residue being burnt a small quantity of a greenish-coloured ash remains. This fuel has the specific gravity 1·173, and the assay results showed:—

Fixed Carbon.	Volatile Matter.	Hygroscopic Moisture.	Ash.
47·81	45·91	2·05	0·63

A complete analysis gave the following results:—

Carbon.	Hydrogen.	Sulphur.	Nitrogen.	Oxygen.
60·59	8·63	4·23	1·43	25·12

* *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting, 1892 (advance proof); see also *Journal of the Iron and Steel Institute*, 1888, No. I., pp. 110–124.

† *Journal of the Iron and Steel Institute*, 1892, No. I., p. 313, and No. II., p. 350.

‡ *Journal of the Society of Chemical Industry*, vol. xii. pp. 221–222.

§ *Chemical News*, vol. lxvi. p. 211.

Using the Berthier method of ignition with lead oxide, a calorimetric effect of 5405 calories was obtained, the button of lead reduced by one gramme of the fuel being 23·102 grammes in weight. The ash of this lignite most unexpectedly showed the presence of large quantities of vanadium, the results showing as much as 38·22 per cent. of V_2O_5, 80 per cent. of which was present either as the oxide or as an alkali salt, being soluble in hot ammonia water. The ton of lignite contains 4½ lbs. of V_2O_5, and its ash forms perhaps the richest known ore of vanadium that occurs in any quantity.

Coal at Bryncoch.—A seam of coal six feet in thickness has been struck at a depth of 430 yards at the new pits of the Main Colliery Co. at Bryncoch, near Neath. These pits had been sixteen months in process of sinking, during which period more than 100 yards of very hard rock had been passed through.*

The Wigan Cannel-Coal.—Mr. G. Caldwell † recently exhibited some fossil plant remains from the Wigan four-foot mine, and describes the cannel-coal seam found there. This seam practically occurs only under the township of Abram, where it reaches a thickness in places of six to eight feet, tapering off in all directions down to nothing. The top coal is generally about the same thickness of six to eight inches, and the bottom coal averages from 2¾ to 3¼ feet, but on its upper side partakes largely of the nature of cannel where that coal is the thickest.

The Lanarkshire Coalfield.—In a paper read before the Philosophical Society of Glasgow, Mr. R. T. Moore,‡ describing the recent development of the Hamilton coalfield, observes that in 1845 the total quantity of coal raised in Scotland was estimated at 4,000,000 tons. In 1891 this had increased to 25,000,000 tons, of which 14,000,000 tons was from Lanarkshire. The output of the Hamilton field was 1,200,000 tons in 1856, and 7,500,000 tons in 1890. The upper group of Coal Measures in this field will be exhausted, the author thinks, in twenty-four years, and the whole of the coal in sixty years.

Coal in the North of France and in the South of England.—Professor M. Bertrand § has carefully studied the question of the cor-

* *Mining Journal*, vol. lxiii. p. 129.

† *Transactions of the Manchester Geological Society*, vol. xxii. pp. 211-215.

‡ *Mining Journal*, vol. lxiii. p. 165.

§ *Annales des Mines*, 9th series, vol. iii. pp. 5-83 (with 2 plates.)

relation of the coalfields of the North of France and of the South of England, and concludes that the Dover coalfield is distinct from that of the Pas-de-Calais. The continuation of the axis of the former coalfield is concealed beneath the sea. It is probable, from an examination of contour lines of the sea-bottom, that this axis will come out on the French side a little to the east of Calais, and does not, consequently, meet the second coalfield.

Discovery of Coal in the Eifel.—According to Grebe,* coal has been discovered at Neunkirchen in the Eifel. On sinking an exploratory shaft four yards in depth, two nearly vertical seams of carbonaceous material were found. The author, as Government geologist for the district, then reported that the deposit was so insignificant that further explorations were undesirable, more particularly as the strata of the same age (Greywacke formation) have not hitherto been known to contain workable coal-seams. In the meantime, however, the shaft at Neunkirchen was continued, and the seam was found to have increased in width, being as much as 30 inches in width at a depth of nine yards. The coal is anthracitic in character, and yields 15 to 20 per cent. of ash. Further explorations are required to determine whether the coal-seam is a workable one.

The Ruhr Coalfield.—The methods of working adopted in the Ruhr coalfield were described in a previous abstract.† Dr. W. Runge ‡ has now published a full description of this field. A few years ago he published a very complete sectional map of this coalfield, which field in 1890 produced 35,213,398 tons of coal. Frequent reference is made by the author to the coal deposits of Ibbenbären and Osnabrück, distant some fifty miles from the Ruhr district. The output from these deposits was, in 1890, 242,098 tons.

The Ruhr coalfield strikes east-north-east for about sixty miles, with a breadth of from nineteen to twenty-four miles. For the whole of this extent of 711 square miles it is known to be coal-bearing. The limits of the field, both to the north and east, are still unknown. Of the above 711 square miles only 457 are being actually mined. Towards the west, south, and south-east the subcarboniferous series, culm and mountain limestone, and the Devonian occur in concordant position.

* *Kölnische Zeitung*, March 22, 1893; *Berg- und Hüttenmännische Zeitung*, vol. lii. pp. 127-128.

† *Journal of the Iron and Steel Institute*, 1892, No. II., p. 416.

‡ *Das Ruhr-Steinkohlenbecken*, p. 371, 12 plates. Berlin, 1892.

This is not so, however, towards the north and the east. The coal-seams and the underlying rocks have been folded, the folds having a north-easterly strike. This took place at the end of the Carboniferous period. Since then the various faults have come into existence. The conditions of the deposition and faulting are discussed. All kinds of coal are met with in this basin, from anthracitic coals to long-flame non-caking coals. The coal found in the various seams varies with its position in that seam along its strike, the caking capacity increasing as a rule towards the east end of the seam. The deeper seams approach the anthracites in character, and the whole series of coals, non-caking, caking, and again non-caking, appear to be passed through in regular order. The specific gravity of the coal found varies between 1·25 and 1·4. As many as ninety-one coal-seams of workable thickness are known to exist in this field, the working limit being placed at 20 inches. The average number of such seams is seventy-one, with a total thickness of coal of 226 feet. The average thickness of each seam is thus 3 feet, but many exceed 6 feet. Cannel-coal is found in small quantities with the bituminous coals. Ten tons of coal occupies the following space:—Unpicked, and as raised, 388 cubic feet; as "lump" coal, 431 cubic feet; as nuts, 448 cubic feet; and as dust 418 cubic feet. For the purposes of rough calculation, it may be assumed that one cubic metre of the seam weighs one ton. Considering the future annual output of this field to be equal to that of 1891, the workable coal already known will last for over 800 years to come. In places the field is very wet and gassy, and the coal is often much broken up. The cost of mining the ton of coal varies between 5s. 7d. and 8s. 5d. Fifteen per cent. of the coal mined in this field is converted into coke.

Faults in the Waldenburgh Coalfield.—R. Althans * describes a series of intrusive deposits which occur in this coalfield. These pass alike through the coal-seams and the overlying beds without being in any way connected with side or vertical throws. They are either round or of lozenge shape. They are fissures filled with sandstone, or with a breccia composed of pieces of sandstone, conglomerate, slate, clay, coal, and occasionally porphyry, and are in reality deeply eroded portions of the country which have subsequently become filled with other materials. They are older than the faults.

The Anthracite Deposits of Roumania.—Professor A. O.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 563.

Saligny * describes the deposits of anthracite which occur near Skela and in the Badeanca Valley of Roumania. The Skela deposits have only been known for a few years, having been exposed by surface workings in 1889. The discoverer proved the deposit to extend for about a mile. The roof consists of shale, and the floor of a hard compact sandstone. The deposits occur in the Mesozoic horizon. Analysis shows this anthracite to contain—

	Per Cent.
Hygroscopic water	5·20 to 7·03
Volatile combustible matter	1·93 to 6·67
Fixed carbon	86·75 to 90·29
Ash	0·61 to 2·55

The total percentage of sulphur varied between 0·27 and 0·41. Only from 0·03 to 0·05 of this remained in the ash after the combustion of the fuel, the rest being volatile. Apart from water and ash, two dried samples showed, on combustion, the following composition :—

	1.	2.
	Per Cent.	Per Cent.
Carbon	95·01	97·59
Hydrogen	0·83	1·42
Oxygen+nitrogen	4·16	0·99
Totals	100·00	100·00

The Skela anthracite is deep black, has a vitreous lustre, and a density of 1·78. Its hardness varies between 2 and 3. It decrepitates violently when heated in a muffle.

The anthracite of the Badeanca Valley, in the Muscel district, is of still more recent discovery. It is a true anthracite, and not an anthracitic coal, such as is found at Boteni, in the same district. It closely resembles in appearance the Skela anthracite, though it is somewhat less dense, but it burns with greater readiness, leaves a browner ash, and contains a higher percentage of sulphur. An assay made by the author shows it to contain—

Hygroscopic Water.	Volatile Combustible Compounds.	Fixed Carbon.	Ash.	Total.
3·77	4·64	89·49	2·10	100·00

The total percentage of sulphur was 1·70. A complete analysis gave—

* *Buletinul Societatii de Sciinte Fizice*, Bucharest, 1892, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 545–546.

Hygroscopic Water.	Carbon.	Hydrogen.	Oxygen, Nitrogen, and Sulphur.	Ash.	Total.
3·77	90·40	1·70	2·03	2·10	100·00

or, without either ash or water, 96·05 per cent. of carbon, 1·80 per cent. of hydrogen, and 2·15 per cent. of oxygen, nitrogen, and sulphur taken together. When heated in a closed vessel, this anthracite gave 4·93 per cent. of volatile products, leaving a solid residue which weighed 95·07 per cent. of the weight of the fuel retorted. When similarly treated, two samples of the Skela anthracite gave respectively 4·10 and 7·14 per cent. of volatile products, with 95·90 and 92·86 per cent. of solid residue or "fixed carbon." Other details as to the extent or thickness of these beds are not given, and the fuel does not as yet appear to have been mined to any very important extent.

The Sabero Coalfield.—This Spanish coalfield has hitherto remained unworked, owing to the want of transport. Now, however, a railway has been constructed between La Robla and Valmaseda, and this passes through the Sabero district. M. D. L. Mallada,* who has inspected this district, estimates that in a group of mines he examined there exists 32,538,450 tons of coal. This coal contains only a moderate percentage of ash, and yields from 80 to 84 per cent. of coke. It is stated to be of good quality.

Coal in the Caucasus.—According to R. Helmhacker,† in the northern flank of the Caucasus chain two distinct Carboniferous horizons are met with. On the Kuban River, the sandstone strata, in which the coal-seams occur, are upheaved by porphyry. On the right bank of the river the coal is being worked, mining operations dating back to the year 1846.

The bituminous shale of Jurassic age is also of economic importance. Near Gunib, a seam, varying in thickness from 2 feet to 6 yards, occurs. Although the shale contains too large a proportion of ash and of pyrites, it is used as fuel, some 1150 tons being raised annually.

The most important deposit of Liassic coal is at Tkvibul, thirty miles north-east of Kutais. The total thickness of coal is 50 feet. From the three mines working this deposit, some 1600 tons of coal is annually raised.

Lignite occurs on the Kury River. The lignite is of a black colour, has a conchoidal fracture, and contains 15 per cent. of ash. The author

* *Revista Minera*, vol. xliv. p. 87.

† *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 409-411.

gives particulars of the various seams and a sketch of the geology of the district.

In a subsequent paper, N. Syrkin * gives further particulars of the results obtained from an investigation of the Tkvibul Colliery. The coal gave on analysis the following results :—

Carbon.	Oxygen.	Hydrogen.	Sulphur.	Nitrogen.
78·42	14·09	5·13	1·32	1·04

Coal in Poland.—In the course of an elaborate report on the industrial resources of Western Russia, J. Couharevitch † states that the coal measures occupy a large portion of the Bendzin district in the province of Petrokov. The town of Dombrowa gives its name to the coalfield; although it is known that this coalfield is merely an extension of that of Silesia. The coal occurs in two varieties, brilliant and dull, the former being the more bituminous. Neither variety gives a firm coke. No fire-damp is liberated from the Dombrowa coal. The transverse axis of the basin has a length of 6 miles, and trends north-east south-west. The mean length is 12 miles. The series includes the main seam, which varies in thickness from 16 to 60 feet, with seven seams above and six seams below, varying from 3 to 5 feet in thickness. The Dombrowa coal gives on analysis 66 per cent. of carbon, 5 per cent. of hydrogen, and 4 to 11 per cent. of ash. The production of this coalfield in 1891 was 2,545,454 tons from seventeen shafts, forming twelve distinct undertakings.

The so-called Cannel-Coal of British Columbia.—Mr. D. P. Penhallow ‡ has made a careful microscopical examination of a number of specimens of a coaly mineral having the general properties of a cannel-coal, and locally recognised as such, from the Kootanie and Lower Cretaceous formations of British Columbia. From the character of the mineral, as determined by microscopical examination, from its fracture and colour in transmitted light, as well as from its combustible nature, the author concludes that it represents some form of mineral resin.

Coal in Newfoundland.—Of the undeveloped minerals of Newfoundland, Mr. C. Fane § regards coal as the most important. Two extensive coalfields have been discovered, one near St. George's Bay, in

* *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 427–428.
† *Revue Universelle des Mines*, vol. xix. pp. 265–335.
‡ *The American Geologist*, vol. x. pp. 331–339, with plate.
§ *Journal of the Society of Arts*, vol. xli. pp. 477–491.

close proximity to large deposits of iron ore, and the other near Deer Lake, on the Humber River. Both of these coalfields are at no great distance from the coast, and should prove of importance.

In the St. George's Bay coalfield, the aggregate thickness of the seams gives 20 feet of coal, and there are good grounds for believing that other seams, not yet discovered, exist in this neighbourhood. The coal of the Cleary seam is a bituminous caking variety, leaving a nearly white ash. The coalfield of Deer Lake is quite as promising as that of St. George's Bay, but neither of them has been fully explored as yet.

Canadian Coals.—A sample of coal from the second seam of the Drummond Colliery was found to give on assay :—

Fixed Carbon.	Volatile Combustible Matter.	Moisture.	Ash.
68·14	22·32	1·08	8·46

A coal from the North Thomson district, British Columbia, has been tried with success on the line of the Canadian Pacific Railway.*

Coal in Natal.—Mr. R. A. S. Redmayne,† in discussing the coal industry of Natal, states that at one place he struck with the diamond drill a seam of coal 13 feet 2½ inches thick at a depth of 172 feet. Of this thickness 12 feet 6 inches was coal. The coal showed on assay :—

Moisture.	Volatile Hydrocarbons.	Fixed Carbon.	Sulphur.	Ash.
1·68	10·84	71·32	0·88	15·25

It was thus an anthracitic coal of good quality.

At the Southern Cross Colliery there is a workable thickness of coal in one seam of 3 feet 7 inches. This coal yields 11,000 cubic feet of gas per ton, and 69 per cent. of coke. At the neighbouring Newcastle Colliery there is believed to be 20,000,000 tons of coal available. The belt of coal-bearing land adjacent to the line of railway from Eland Lalaate to Newcastle is divisible into three sections. One of these lies south of the Biggersburgh Range, a second is the Dundee Plateau, and the third the Newcastle district. In the Biggersburgh district the seams are mostly thin. Thus at the Natal Colliery there is a sandstone roof, then 2 feet 2 inches of coal, next a shale band 9 inches thick, and then another seam of coal 16 inches in thickness with a sandstone floor.

* *American Manufacturer*, vol. lii. p. 64.
† *Mining Journal*, vol. lxii. p. 1478.

In the Dundee district the coal is considerably thicker. Labour is cheap. The Natal coal is stated by the author to be much better than that of the Transvaal.

A bore-hole which has been put down near Dundee, Natal, struck a coal-seam at a depth of 292 feet. Passing through sandstone, a further seam of coal was struck at a depth of 347 feet. The lower seam is much the thicker of the two; it averages about 5 feet.*

Coalfields in New South Wales.—Mr. J. R. M. Robertson† gives a description of the coalfields south of Sydney, New South Wales. The Coal Measures are quite distinct from those of Europe. They are overlain by the Hawkesbury sandstones, which contain no distinctive fossils, but are probably coeval with the Permian series. Over them are the Wianamatta shales. At Wollongong in Illawarra the coal-seams are most numerous, and the measures attain a thickness of 700 feet, which rapidly thin off to 150 feet thirty miles to the west, but subsequently thicken again. The various seams are described by the author, and the following ultimate analysis of the coal from the upper seam is given as a fair average of the existing Illawarra collieries :—

Moisture.	Carbon.	Hydrogen.	Oxygen.	Sulphur.	Nitrogen.	Ash.	Total.
0·40	79·66	5·36	3·68	0·49	0·67	9·74	100·00

The question of labour is discussed, and an account is given of the various faults and dykes in the district, sections being given to show the action of the dolerite in the seams. For all practical purposes the Illawarra field is confined to a few collieries, all coal-land of value being acquired. The lower seams, except in a few places, are not of good quality, and even in these they are inferior. Some trials have been made to determine extensions of this field, but without very satisfactory results. The iron ores of the district are unfavourably mentioned by the author, but the kerosene shale or coal is said to occur in some quantity, and to be of exceptional quality. The correlation of the northern and southern fields is shortly discussed.

In a subsequent paper, Mr. J. R. M. Robertson‡ gives a detailed account of the occurrence of torbanite or kerosene coal in the colony of New South Wales, a general description of the whole coalfield being also

* *Mining Journal*, vol. lxiii. p. 443.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 83-111, with map and plate.

‡ *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 88-112, with five plates.

given. The distinguishing features of the torbanite deposits are their great irregularity. They are generally of rather limited extent, and are found in more or less lenticular beds, which vary very greatly both in quality and thickness within a very short distance. The oldest and best deposit is that at Hartley vale, and the next best that at Joadja, eighty miles distant. With the exception of the deposit at Murrurundi, the kerosene coal has only been found in the southern and western districts, and never in the Newcastle or Rathluba measures. At Hartley vale the deposit was worked very wastefully on a pillar and stall system, but nearer the edges of the deposit a longwall system was ultimately adopted. The latter method is also used at Joadja. All the deposits contain mineral of two qualities, the better kind yielding 150 to 160 gallons of crude oil, and 20,000 cubic feet of 48 candle-power gas per ton. The plant at present used for extracting the oil is antiquated and wasteful. Some assays of the mineral from various localities give the following results:—

Description.	Mt. Kembla.	Wigan.	Hartley.	Murrurundi.	Capertee.
Volatile hydrocarbons .	37·60	45·90	83·87	71·88	64·70
Fixed carbon . .	22·21	45·52	8·03	6·46	20·95
Ash	40·2	7·12	7·07	19·93	13·50
Sulphur . . .	...	...	0·58	0·54	0·80
Moisture . . .	...	...	0·44	1·65	0·85
Specific gravity . .	...	...	1·05	...	1·17

Professor Boyd Dawkins* describes the coalfields of New South Wales as consisting of three groups, belonging to the Carboniferous, the Permo-Carboniferous, and the Permian ages. The area of the coal-bearing rocks of New South Wales, between the Blue Mountains and the sea, is computed at about 18,000 square miles, and there are other beds in inland districts of about equal extent. The amount of available coal in seams over 2½ feet thick and within 4000 feet of the surface in New South Wales was estimated by Mr. Wilkinson as amounting to 78,198 millions of tons, or about the same quantity as the coalfields of Great Britain within the same limits of depth, but including seams over 2 feet thick. Professor David's calculation was 130 to 150 thousand million tons. The quality of the coal is variable, being bituminous, splint, or steam coal, and coking or non-coking. The beds are so placed as to be readily accessible, and workable without deep mining. The coal-beds of New South Wales in regard to quantity, quality, and

* *Transactions of the Manchester Geological Society*, vol. xxii. pp. 160–178.

general accessibility are without a rival, and must ultimately make the Colony the great manufacturing power in the southern hemisphere. Mention is also made of the fossil characteristics of the deposits.

Coal in Victoria.—A bore-hole now being put down at Korumbarra, Victoria, in sandy shale, struck at a depth of 384 feet a 3-inch seam of coal; an 8-inch seam was struck at a depth of 414 feet; a similar seam at 425 feet; an 18-inch seam at 450 feet; one of 12 inches at 461 feet, and another 12-inch seam at a depth of 642 feet.*

Coal at Alford Forest, New Zealand.—According to Mr. H. A. Gordon,† near the foot of Mount Somers there are coal-seams, the largest being 7 feet in thickness. At some places the seams appear to be dipping at an angle of 45° to the westward, and in one place the seams are nearly horizontal. The quality of the coal is similar to that of the brown coal found at other localities in New Zealand. Analysis yielded the following results:—

Fixed Carbon.	Volatile Matter.	Water.	Ash.
47·58	39·95	10·41‡	2·06

The value of this coal property depends largely on the market that can be obtained for the limestone by which it is accompanied.

The Coalfields of Montana.—The coalfields of the Sweet Grass Hills and of the Flathead Valley, in the north-west of Montana, are described by Mr. W. H. Weed.§ Two seams have been found in the first-named field, an assay of one of the coals showing—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
11·62	37·16	46·57	4·69

Further particulars‖ of the Flathead basin are also given, with sections of the coal-seams.

The Sharon Coal of North-Eastern Ohio.—It is well known that boulders, ranging in size from a few cubic inches up to several cubic feet, are occasionally met with in coal-seams. Mr. M. Stirrup has described a number of such occurrences in the vicinity of Manchester.

* *Australian Mining Standard*, vol. ix. p. 135.
† *Report on the Mining Industry of New Zealand.* Wellington, 1892, p. 140.
‡ In the original this percentage is given as 16·41.
§ *Engineering and Mining Journal*, vol. lv. p. 197.
‖ *Journal of the Iron and Steel Institute*, 1892, No. II., p. 363.

In the United States, Ohio has furnished the largest number, if not all, of the cases reported. These are, without exception, composed of grey quartzite; they are well rounded, polished, and striated; and they have all been derived from a single coal-seam, the Middle Kittanning seam.

Mr. E. Orton * now describes a new example of these boulders recently brought to light. It is of interest in that it is the first boulder that has been reported from the Sharon seam, the lowest member of the series. It is, too, not a metamorphic sandstone or quartzite, like those previously found, but is an excellent example of vein-quartz. It has not been worn by water or glacial action, but is angular as if freshly broken from the parent mass. No satisfactory explanation of these facts has yet been advanced.

Coal from the Cumberland Field.—The following is an analysis of coal from the George's Creek Mines of the Cumberland, United States, coalfield :—

Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Moisture.	Volatile Sulphur.
79·40	5·11	3·80	1·25	9·24	0·58	0·62

The calorific value shown by a Thompson calorimeter was 13,452 heat units, and that by a working boiler test 10,817.†

The Pennsylvania Coalfield.—Mr. H. A. Wasmuth ‡ gives some notes on the stratification of the northern anthracite coalfield of Pennsylvania, describing the effect that the Susquehanna River had on the coal-seams in conjunction with faults in producing wash-outs and other troubles. To avoid flooding the mines, considerable pillars of coal have been left under the old river-bed, and coal has thus been wasted. A method of working is proposed to obviate the dangers due to flooding by robbing several of the pillars so as to produce a uniform break across the strata, and so to shut off the old river-bed by letting down the top clays.

Mr. B. S. Lyman § gives an account of an occurrence of coarse conglomerate above the Mammoth anthracite bed in Pennsylvania, with notes of other localities in which conglomerate is also found above the coal.

* *American Journal of Science*, vol. xliv. pp. 62–63.

† *Iron Age*, vol. li. p. 297.

‡ *Journal of the Franklin Institute*, vol. cxxxiv. pp. 354–358, with plate.

§ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

It has frequently been inferred in this region that there is no coal under the conglomerate, and the error of this assumption is now shown. The geological character of the conglomerate is discussed.

The Coal River Basin, West Virginia.—The Coal River Basin forms a large part of Logan and Raleigh counties, and the whole of Boone county, Ohio. It comprises about 650,000 acres. A seam of cannel-coal exists in this field with an average thickness of 4½ feet. There are also three seams of bituminous coal, one of which reaches in parts a thickness of from 11 to 14 feet.*

Coal in the Argentine Republic.—Dr. F. Moreno † describes the discovery and occurrence of coal at San Rafael, in the province of Mendoza, Argentine Republic. The lower seams occur at an altitude of about 8250 feet above sea-level. They are very numerous, varying from 4 inches up to 13 feet in thickness, this latter seam occurring at an altitude of 10,560 feet. It is in the coal of this district that vanadium has been shown to exist in such large quantities. The coal is stated to be about equal in quality to that of the Marles field. An extensive coalfield is reported to have been discovered in the province of Neuquen, and it is supposed to be a continuation of the San Rafael field. The coal yields on assay from 57 to 61 per cent. of coke, and has a calorific power of about 4570 to 4636 calories.

Coal in Peru.—In a lengthy paper on the mining and metallurgical industries of Peru, E. Haber ‡ gives some interesting details relating to the occurrence of coal. In the Cretaceous limestone there are zones in which coal-seams are met with, alternating with marly sandstone. The seams are of no great thickness, the maximum never exceeding 6 feet. The coal itself is generally impure, and almost always bituminous.

In the San Pedro Colliery, in the Cerro Páncar, the coal is worked by an adit level, 122 feet in length, driven in the hillside. The seam, which courses from west to east, has a dip of 40° to the north, and a thickness of 10 inches. The enclosing rock is an argillaceous bituminous shale. The cost of mining the coal is sixteen sols (64s.) per ton.

More important and extensive seams of similar character occur near the longitudinal axis of the Sierra. The most important centres of mining

* *American Manufacturer*, vol. lii. p. 64.

† *Ibid.*, p. 636.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xl. pp. 187–222.

operations are at Huaypacha and at Suitucancha. The coal mined is impure, very bituminous, and ignites with great facility. The coal from the latter locality is coked in open heaps, and the product, notwithstanding its high percentage of ash, is used in the blast-furnaces at the Carmen Works, near Yauli.

As the cost of mining and transporting the coal is very high, the consumption of local coal for industrial purposes is exceedingly limited, and the purer and but slightly dearer English coal is preferred. In consequence of the small consumption, the development of the coal-mining industry in Peru has hitherto been very insignificant.

Coal in China.—At the coal-mines at Wang-san-shih there are three seams worked, 24 feet, 3 feet, and 14 feet respectively in thickness, dipping 50° S. A perpendicular shaft has been sunk to a depth of 106 feet, and is still being sunk at the rate of 4 inches per hour. This coal is three miles from a line of railway, and six miles from iron ore deposits, but is a non-caking variety *

Coal in the Mergui District.—Mr. T. W. H. Hughes † reports the discovery of further deposits of coal on the Great Tenasserim River. A trial pit was put down on the Htiphanko stream, and a seam 12 feet 7 inches in thickness was encountered, the total thickness of coal being 7 feet 7 inches. The coal is chiefly a hard black variety with conchoidal fracture and shining lustre. It does not soil the fingers, and in this respect differs from most of the Indian coal of younger age. An assay of the coal yielded the following results :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Total.
11·34	36·40	43·27	8·99	100·00

Notwithstanding the large percentage of moisture, this is excellent coal compared with the ordinary run of Indian samples. Making very large deductions for waste, the author is of opinion that the deposit contains a million tons of workable coal.

The Héraclée Coalfield in Asiatic Turkey.—An account of the Héraclée coalfield in Anatolia is given by J. D'Harveng.‡ Its length is estimated at a hundred miles, and to some extent it resembles the Belgian field, as the coal is of uniform quantity throughout each seam.

* *The Australian Mining Standard*, vol. viii. p. 322.
† *Records of the Geological Survey of India*, vol. xxvi. pp. 41–43.
‡ *Revue Universelle des Mines*, vol. xx. pp. 34–70, with map and section.

The base of the Coal Measures consists of thin sandstone underlain by shales of considerable thickness. The thickness of the coal-bearing strata is about 22 yards. The beds above the coal are of Triassic age, but disappear in parts. Particulars are given of the stratification, and the various seams that occur are described in detail. There are twenty-five seams that have been worked, with a total thickness of 137 feet of coal, or an average of 5 feet 10 inches. There are seventeen others that may also be worked, raising the total number to forty-two, with a mean thickness of 3¼ feet. The field is divided into three important series of outcrops. Between Cozlon and Tchatal-Agzy, the seams dip at 45°, increasing to 60° at times, and are faulted in several places. The outcrops between Armontchouk and Tchaouss-Agzy are less important, but have been worked on the sea-shore. The outcrop at Kirimsa is but little known. The existence of coal has been known for a considerable length of time, and considerable impetus was given to the output during the Crimean war. The workings are primitive, and there are some restrictions on labour. Generally some form of pillar workings is employed. Levels are driven and connected by cross-cuts as far as possible, and then the pillars are taken out from the far end. The author then discusses the wages, timbering, concessions and taxes, the cost of production, and the production and consumption. Coke has been made from this coal, but it is of no industrial value.

The Value of Peat as Fuel.—In an exhaustive report on the use and value of peat as fuel, Mr. T. W. Gibson * discusses the peat industry of Scotland, Ireland, and America. The various processes of preparing peat for fuel are reviewed, and the value of peat charcoal for iron furnaces is pointed out. From the facts presented he draws the following conclusions:—The peat bogs of Ontario are of great extent, and their future importance can hardly be over-estimated, if an economical process be devised for the manufacture of a good fuel from this material. Air-dried peat is not likely to come into general use in Ontario so long as wood and coal do not rise materially above their present price. The tendency of these two fuels to rise in price will undoubtedly have the effect of directing attention to other kinds of fuel, of which peat is the most important. A first-class fuel may be produced from the crude material by various methods of condensation and compression, particularly when coupled with the production of artificial heat; but such processes have hitherto been conducted at too great a cost. As a source of

* *First Report of the Bureau of Mines of Ontario*, pp. 180-211. Toronto, 1892.

gaseous fuel, however, peat offers considerable advantages. The progress now being made in the effort to manufacture a first-class fuel from peat affords grounds for hoping that such fuel will shortly be available in Ontario. Before the problem of peat fuel is satisfactorily solved, however, many improvements in methods may yet be found necessary.

A report has recently been issued by the Foreign Office * dealing with the results of inquiries on the manufacture of fuel and other products from peat. In Jutland peat moors extend over ninety square miles, but all methods of treatment have been found to be impracticable or impossible. At the present time a small amount is used in Denmark for local consumption. It is simply cut and dried, or pressed into blocks.

In the Brest and Cherbourg consular district there is no peat industry of any account. Some is cut near Marseilles and used at Lyons. Peat bogs are found around in the Bordeaux district, and 7000 tons are cut annually in the Charente district. Some peat fuel is used in Paris.

In Germany peat is used locally, but it does not pay as a rule to carry it more than twenty miles. No statistics are available, but it is estimated that 150,000 tons are burnt annually in the Grand Duchy of Oldenburg. The method of cutting and drying peat at Carolinenhurst is given. The peat is cut to a depth of 3 to 5 yards. The upper 4½ feet is used for litter and the remainder is cut into blocks, which are air-dried in pyramidal stacks. The German exports of peat in 1891 is given as 11,457 tons, and imports 13,073 tons.

In the Netherlands black turf is used in brick-kilns along several of the rivers. The peat is dug between the middle of March and the middle of June, and is water-borne after drying. In Holland turf is also used in the natural state, besides which it is carbonised in heaps or in ovens, but the product is very porous.

In Russia peat is found in forty-five provinces over an area of 67,000 square miles, and is extensively used in manufactures and also for locomotives.

In Sweden and Norway peat is largely used as domestic fuel, but has not come into much use for manufacturing purposes. Some ironworks use a small quantity mixed with other fuel. About 25,000 to 30,000 tons are used yearly for metallurgical purposes.

Peat Ash.—Ash from the Buchscheiden peat, analysed by Dr. E. Prziwoznik † in the laboratory of the Government Assay Office in Vienna, gave the following results:—

* *Foreign Office Report.*

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. p. 482.

Fe_2O_3.	Al_2O_3.	CaO.	MgO.	Alkalies.	CuO.	SiO_2.	SO_3.	P_2O_5.
22·98	10·72	26·78	4·26	0·57	0·43	15·40	18·12	1·26

The ash, therefore, contains 16·09 per cent. of iron, 0·034 per cent. of copper, 7·259 per cent. of sulphur, and 0·552 per cent. of phosphorus.

III.—*CHARCOAL.*

Charcoal-Burning.—At Vansbro, in Sweden, is a school for the teaching of charcoal-burning. In 1891, the students of this school burned eleven piles of wood, containing altogether 1007 cubic yards of wood, the yield of charcoal varying from 56·0 to 60·8 per cent. A similar school exists at Hagfors, and here the students burnt seven piles of wood, containing altogether over 38,000 cubic feet. The average yield of charcoal was 53·6 per cent.* The annual reports on these schools by L. Wenström and C. G. Wikström have been published.

Peat Charcoal.—Experiments have been made in Sweden by Forsberg,† in which the peat was placed in a cast-iron tube 6 feet 7 inches long and 12 inches wide, and the tube subsequently heated in the channel for the escaping gases of an open-hearth furnace. The peat once introduced into the retort, this was closed by a sheet of metal. In the centre of this metal cover were two holes, each 0·4 inch in diameter. These holes could be closed at will during the retorting by means of iron plugs. After from 3 to 3½ hours the charge of peat was completely carbonised, this being observable by the change in colour and combustibility of the gases escaping from the holes in front of the retorts. The percentage yield of fixed carbon was about the same as that from wood. The process being, however, a tedious one, heap charring was adopted in place of the retort. This was completed in 3½ days, and the out-turn was the same as that from the previous experiments in retorts. The peat had only been very slightly pressed together, and the percentage of ash it contained was high. The resulting charred mass showed a marked tendency, during the two first days after the completion of the distillation, to crack and to decompose entirely, but after that period it became more compact, though not to a great extent. This peat charcoal was then experimented with in an open-hearth furnace. It was mixed with an equal

* *Jernkontorets Annaler*, vol. xlvi. pp. 380–385.
† *Ibid.*, pp. 374–377.

bulk of charcoal, and then used in the melting down of finery blooms. It was found that a very large quantity of slag soon formed, fusion was rendered much more slow, and might even have failed altogether had not the slag been tapped off. That done, the fusion was completed satisfactorily. The resulting metal was soft, but contained far too much slag, although the actual quality of the iron had not been much deteriorated. Another experiment was then made with the peat charcoal alone, no wood charcoal being employed. The furnace working did not change so much as might have been expected. The time required was the same as when ordinary charcoal was used, but during the melting down such a large quantity of slag was formed that it had to be tapped out of the furnace continually. In appearance the fused metal, before it had been struck by the hammer, did not appear to differ from that obtained under ordinary conditions, but after being hammered for a while it fell into two or three pieces. The next experiments were made in the Franche-Comté hearth, the peat charcoal being used exclusively in the welding of bar iron. A saving of 35 or 40 per cent. of fuel resulted from its use as compared with the consumption of ordinary charcoal, and the resulting bar was of good quality. For welding purposes this fuel appears to be an excellent one, but for others, like those described in which the fuel comes into direct contact with the metal, its use does not give satisfaction.

G. Angel,* of Jönköping, Sweden, compresses peat into bricks. These are then placed in close retorts, and heated to a temperature of 250° C. It is stated that the gases produced by the distillation undergo decomposition within the peat, producing a compact carbonaceous residue.

IV.—*COKE.*

Analyses of Austrian Coke.—Dr. E. Przíwoznik † gives the following results of analyses of coke conducted in the laboratory of the Government Assay Office in Vienna:—

Description.	*a.*	*b.*	*c.*	*d.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ash	8·51	7·76	8·90	9·87
Sulphur	0·51	0·64	0·66	0·78
Phosphorus	0·057	0·061	0·086	0·084

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 551.

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. p. 48.

a. coke from the collieries of Count Wilczek at Ostrau; *b.* from the collieries of Count Larisch at Karwin; *c.* from the collieries of Prince Salm in Moravian Ostrau; and *d.* from the collieries of Gutman Brothers at the same locality.

The Manufacture of Coke in New Zealand.—Mr. J. Harrison * states that the West Coast Brunner coalfield contains a coal which when coked in ordinary beehive ovens yields a coke of high quality. At present two collieries are at work in this field, raising several thousand tons of coal a week. A section is given showing the characteristic features of this coalfield.

Alabama Coke.—Dr. W. B. Phillips † gives a number of assays of several varieties of coke made in Alabama, and also their ultimate analyses, with the colour of the ash and the crushing strength. There are now between 5500 and 6000 beehive ovens in this State, and also 82 Thomas ovens. The sulphur in these cokes ranges from 0·79 to 2·21 per cent., the ash from 1·80 to 16·60 per cent., and the breaking strain from 300 to 1100 lbs. per square inch. The most remarkable result among those given is the slight difference in composition between the 48 and the 72 hour coke—De Bardeleben coke, which broke at 750 and 1100 lbs. per square inch respectively. The two assays are given below :—

	Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash
48-hour coke . .	0·40	0·70	86·00	1·23	12·90
72-hour coke . .	0·05	0·90	87·25	0·99	11·80

and the ultimate composition as follows :—

	Carbon.	Hydrogen.	Oxygen.
48-hour coke	76·23	6·18	3·06
72-hour coke	78·27	7·38	1·54

Coke from Kentucky Coal.—The plant of the Mingo Mountain Company at Middlesborough, Kentucky, comprises 250 coke-ovens in active operation. These make about 300 tons of coke a day. The coke contains about 90 per cent. of fixed carbon, 8 per cent. of ash, and 0·8 to 1 per cent. of sulphur. The main seam of coal at Middlesborough is 6 feet in thickness, and lies above water-level. A ton of this coal yields 10,000 cubic feet of gas.‡

* *Iron Age*, vol. l. p. 1363.
† *Proceedings of the Alabama Industrial and Scientific Society*, vol. ii. pp. 13–19.
‡ *Iron Age*, vol. li. p. 75.

Coke from Connellsville Coal.—Mr. J. Fulton* publishes the records of four tests of Connellsville coal, coked in a beehive oven 12 feet in diameter and 7 feet high at the crown of the dome. The results are tabulated, and it is shown that the coal yielded 66·17 per cent. of marketable coke, 2·30 per cent. of small coke or breeze, and 0·82 per cent. of ash. The total average loss of volatile matter expelled from the coal on coking was 30·71 per cent.

Coal and Coke in West Virginia.—Mr. W. S. Edwards† describes the coal deposits of West Virginia and the coke made from the various coals. He refers to all the principal districts giving assay results of the coals and of the coke made from them, and points out that in the New River district alone 818 coke-ovens are now in operation. He also publishes estimates as to the cost of making coke in the Kanawha and New River districts, the latter district having a slight advantage in the total cost.

Coke-Oven Plant in Tennessee.—The new coke-oven plant erected at Pioneer, Tennessee, consists of eighteen 12-ton Thomas ovens, with one 48-inch Ross disintegrator of 300 tons daily capacity. The ovens are 30 feet long, 12 feet wide, and 6 feet high, inside measurement. The coal is crushed to the fineness of meal before being submitted to the coking process, to ensure purity and uniformity of product. The coke made has averaged about 0·04 per cent. of sulphur.‡

The Otto Coke-Oven.—The manufacturers of this oven give a number of details relating to the results obtained with them in practice. They show that for every part by weight of coal coked, from 1·07 to 1·7 part of water can be evaporated by the gases escaping from the ovens. The percentage of tar collected appears, in the case of the six works tabulated, and which possess 340 Otto-Hoffmann ovens, to have varied in 1892 from 2·85 per cent. to 4·00 per cent. of the coal coked, while the percentage of ammonium sulphate varied from 1·00 to 1·27, calculated on the weight of the coal when dry.§

The Thomas Coke-Oven.—Mr. J. T. Hill‖ describes the Thomas coke-oven plant erected at the works of the Sloss Iron and Steel

* *American Manufacturer*, vol. lii. p. 241.
† *Iron Age*, vol. li. p. 1170. ‡ *Ibid.*, vol. l. p. 1225.
§ *Stahl und Eisen*, vol. xii. pp. 1055-1059.
‖ *Proceedings of the Alabama Industrial and Scientific Society*, No. 2.

Company. The Thomas oven is in reality an improved type of the old Welsh oven. The Thomas oven is much longer, and both ends are movable, but otherwise the two ovens are almost identical. At Coalbury sixty-four of these ovens are in use. Their dimensions are: length, 36 feet; width inside, 7 feet 9 inches in front, and 7 feet 3 inches at the back; height over all, 8 feet; height of door, 4 feet; height inside, 5 feet; fall in bottom from the back door to the front, 1 inch. Both the back and front are movable and have swinging doors, which are in two sections and are built of fire-brick of peculiar shape laid in iron frames. There are three openings on the top—two funnel heads and one draught stack near the rear end of the oven. In front of, and on a level with, the floor of the ovens, is an apron of stone and brick, 8 feet wide, running the whole length of the battery. Four feet below this is a similar apron of masonry 7 feet wide, on which runs the rails for the "dinkey" containing the machinery for drawing the coke. The railway line for the coke-waggons is at a still lower level. The charge of coal is twelve tons, and comparing the results with those resulting from the use of beehive ovens, the author states that the Thomas oven shows that:—(1.) The yield is equal to that of the beehive oven. (2.) The quality of product is fully up to the standard. (3.) That it is practicable to quench the coke outside the oven without detriment to its quality, resulting in leaving the oven hot and dry for the reception of the following charge of coal. (4.) The saving of one handling, by which a large percentage of coke is saved, which would otherwise be rejected as braize. (5.) There is a considerable economy effected by its use, the average cost per ton of coke made during a twelvemonths' run being 44 cents in the case of beehive ovens, and only 29 in that of ovens of the Thomas type.

A New Coke Ejector.—Illustrations have been published * of a coke-pusher to be used in connection with an experimental plant of Semet-Solvay coke-ovens at Syracuse, New York. The pusher proper consists of a heavy beam placed centrally between the two beams of the supporting frame, running on grooved rollers. Upon the front end of the beam is the head entering the oven. The upper portion of the beam carries a rack upon which a pinion engages, driven by a train of wheels from the engine, which is provided with a link reversing attachment. A rail, against which rollers bear, receives the thrust due to the emptying of the oven.

* *Iron Age*, vol. l. p. 1259, 2 illustrations.

The Gases from Coke-Ovens.—A. Hüssener * gives the following analyses of gases passing to the scrubbers from Otto coke-ovens:—

Description.	I.	II.
	Per Cent. by Volume.	Per Cent. by Volume.
Carbonic anhydride	0·90	0·88
Hydrogen sulphide	0·40	0·43
Heavy hydrocarbons	2·33	2·03
Oxygen	0·44	0·41
Carbonic oxide	4·46	4·61
Light hydrocarbons	27·36	24·71
Hydrogen	58·37	61·40
Nitrogen	5·74	5·51
Totals	100·00	99·98

With the specific gravity of air as a unit, the specific gravity of these gases was 0·355. Similar coal treated for illuminating gas in the ordinary way usually shows 2 per cent. by volume of carbonic anhydride and 8 per cent. of carbonic oxide.

Recovery of By-Products from Coke-Ovens.—In discussing the recovery of by-products from coke-ovens, Mr. C. Dreyfus † ascribes the fall of prices of benzene and anthracene to the larger production. The Hoffmann-Otto ovens, for instance, have increased in number from 40 in 1884 to 1205 in 1892 in Germany. One of these ovens cokes 6¼ tons of coal in forty-eight hours. The following details, amongst others, are given by the author:—

District.	Coal Coked per Oven, Tons.	Yield per Cent.			Saving in Coal per Day by Use of Gas, Tons per Oven.
		Coke.	Tar.	Sulphate of Ammonia.	
Ruhr	1125	75–77	2·3–3	1·1–1·2	0·35
Upper Silesia	1170	65–70	4–5	1·0–1·15	0·44
Saar	960	68–72	4–3	0·8–0·9	0·35

Details are also given of the performance of Semet-Solvay ovens.‡ It is now about three years since benzol was recovered directly from the gas, besides tar and ammonia. The process, devised by F. Brunk, is

* *Stahl und Eisen*, vol. xii. p. 967.

† *Journal of the Society of Chemical Industry*, vol. xi. pp. 879–881.

‡ *Journal of the Iron and Steel Institute*, 1892, No. II., p. 373.

kept secret, but it is known that 7 to 16 lbs. of 90 per cent. of benzol is recovered per ton of coal coked. The value of the tar and of the ammonia recovered is also discussed at some length.

V.—*LIQUID FUEL.*

Formation of Petroleum.—Dr. J. J. Jahn * reviews the various theories that have been propounded to elucidate the question of the formation of petroleum, and brings forward further arguments in support of the view that petroleum has been formed from animal remains.

R. Zalozieki † has discovered pyridin bases in petroleum from Boryslaw. This seems to be of importance in establishing the animal origin.

The World's Petroleum Supply.—A general review of the petroleum supply of the world has recently been published.‡ In America the output has decreased in the last two or three years, but the exports have increased. Owing to Russian competition, however, prices have fallen. According to Mr. P. Stevens, an oil-well has recently commenced to flow in Baku, with an estimated yield of 17,742 tons daily. It is situated at some little distance from other wells, and opens up several hundred acres of fresh lands. Canada appears to take the third place of importance as a producer. Sumatra and other oil-producing countries are also referred to.

The Mineral Oil Industry of Scotland.—An account of the mineral oil industry of Scotland is given by Mr. R. T. Moore.§ This industry began about 1850, and in 1891 the output of oil-shale was 2,337,932 tons, chiefly from the calciferous sandstone series. These lie between the Carboniferous limestone and the Old Red sandstone, over an area covering some thirty to forty by twenty-four miles. The proved thickness of shale-bearing strata is about 3000 feet, containing eight recognised seams. The specific gravity of the shale is 1·75. The quantity of oil yielded varies from 30 to 19 gallons per ton, and the thickness of the beds and their distance apart is also very variable.

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlii. pp. 361–376.

† *Monatshefte für Chemie*, 1892, p. 498.

‡ *Board of Trade Journal*, vol. xiv. pp. 393–395.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 36–47, with map and plate.

Upper seams are generally richer in oil and the lower ones in ammonia. Usually the shale is mined by long-wall methods when the seam is under 4 feet in thickness, and by pillar and stall methods in thicker seams. The material has to be blasted and is riddled through a 1-inch sieve, the smalls being left underground. As a general rule, the methods of working are similar to those used in coal-mines.

For the preparation of oil, the shale is passed through breakers, and then distilled in vertical retorts about 28 feet high and placed in benches of 80 back to back. Each retort holds some 30 cwts., 8 cwts. being charged at a time, and a similar amount being discharged below every six hours. The lower parts of the retorts are most intensely heated, and steam is passed in to aid the evolution of ammonia. The products are drawn off and passed through condensers. From 1 to 3 cwts. of coal are used per ton of shale as fuel to heat the retorts. At the present time the industry is rather in a decadent state, owing to competition from other sources.

Petroleum in France.—A. Charlon * reviews the various occurrences of oil and the explorations made for it in France. Oil has been found in the bitumen mines at Pechelbronn in Alsace. At Gabian, Herault, in the Tertiary series, several wells have been sunk, and a small quantity of oil and a good deal of gas have been obtained. Not far from Grenoble, gas escapes from fissures in the soil, and a well has been sunk over 200 yards deep, but without finding oil. In several of the bitumen-yielding districts some prospecting has been done. At Pont Battu, near Riom, a well sunk to a depth of 298 yards passed through gas-bearing layers at about 87, 130, and 214 yards. At this latter depth salt water charged with oil was found, followed by bitumen and heavy viscous oil. At the lowest depth reached, a small amount of oil was also found, but not in payable quantity.

P. Dubreuil and J. de Clercy † describe the discovery of petroleum-bearing beds in the Limagne d'Auvergne. The plain situated at the feet of the Monts-Dome being thought by M. de Clercy to be favourable to the occurrence of petroleum, he caused borings to be made in several places. The first of these reached a depth of 720 feet, but without result, but another, which is now down to the depth of 900 feet at the other end of the field, at Pont-Battu, in the neighbourhood of Riom, has shown the existence of beds impregnated with hydro-carbon gases

* *La Nature*, vol. xl. pp. 81-82.

† *Génie Civil*, vol. xxii. p. 103, 2 illustrations.

and with light petroleums. Various small outbursts of gas were noted during the progress of the sinking. Below 650 feet hard limestone beds were discovered belonging to the horizon denoted by the fossil *Potamides Lamarki*. Below these, again, were various hard clays with thin beds of sand. It is thought at greater depths the petroleum, of which as yet but little has been found, will occur in larger quantity.

Bitumen in Swedish Iron Ore Mines.—In the Swedish iron ore mines, especially those near Norberg and at Dannemora, bitumen is found in considerable quantities. It is stated by Nordenskiöld * that these bitumen deposits are of two kinds, one of which yields on distillation a large quantity of volatile products, and leaves on combustion practically no ash; whilst the other resembles anthracite, yielding but little volatile matter and leaving much ash. In the ash of this anthracitic type, the author has always found several per cent. of oxide of nickel, and up to 3 per cent. of uranium oxide, whilst cerium and gadolinium also occur in this ash. These rare metals are also found in the ash of a coal occurring in the oldest sedimentary rocks of Sweden. It is interesting to observe that uranium is so much more wide-spread in its occurrence, existing even in sedimentary deposits, than has hitherto been believed to be the case.

The Petroleum Deposits of Baku.—In the year 1873 the quantity of petroleum obtained from this district † was only $3\frac{1}{2}$ millions of poods (1 pood = 36 lbs.); but in 1891 the output had reached nearly 290 millions of poods. Owing to the large number of useless bore-holes that have been put down, the cost of raising the oil has shown a considerable increase, and the output from each productive well has diminished by about one-half. The occasional outbursts of oil when first striking the productive layer, though still yielding large quantities, are not by any means as important as they were formerly, and the deeper wells yield an extremely heavy oil containing only 18 to 20 per cent. of petroleum. In the neighbourhood of the station at Gran, on the Transcaucasian line of railway, an important deposit of oil has been discovered, but it differs entirely from that of Baku, containing as it does only 4 or 5 per cent. of petroleum proper, but yielding as much as 80 per cent. of lubricating oil. At Chidyrsinde, to the north of Baku, three oil-bearing

* *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 677.

† *Zap. imp. russk. techn. obszcz*, vol. xxvi. p. 1; *Chemisches Repertorium*, vol. xvi. p. 270.

beds are now known to exist. Though not very rich, the oil is of a very low specific gravity, 0·841 to 0·858. By deeper boring it is probable that richer deposits of oil will be found; hitherto the wells sunk have not exceeded a depth of about 80 yards. At Naphta-Tschala, to the south of Baku, considerable deposits of oil occur. According to N. Kwiatkowski, the oil has a specific gravity of 0·918, and yields as little as 9 per cent. of petroleum of the specific gravity 0·829. Here, too, deeper wells may yield an oil of better quality.

Occurrence of Petroleum in Gaspé, Quebec.—Mr. H. P. Brumell * notes the occurrence of oil in Gaspé county, Quebec, where desultory work has been carried on for many years, the result being the establishment of the fact that deep-seated oil of superior quality exists, though in what quantity future development alone can tell. The oil is obtained from limestone of Lower Devonian or Upper Silurian age.

Petroleum Wells in the United States.—The number of petroleum wells in the United States amounts to about 46,000. Their daily yield of oil approximates to 130,000 barrels.†

Petroleum of the Crow's Neck Pass, Rocky Mountains.—In a paper read at the fifth annual meeting of the Geological Society of America at Ottawa, Dr. A. R. C. Selwyn referred to the enormous quantities of coal which have lately been found in the vicinity of Michel Creek, near the Crow's Neck Pass. After reviewing his work in this district, he went on to describe the petroleum of the South Kootenai Pass, in which two distinct occurrences were noted. One of these is on Cameron Falls Brook, where a heavy dark-brown oil was found floating on the surface of the stream; the other is on Akamina Brook, in British Columbia, where the oil was found in a similar manner, but of much lighter colour and gravity. Both these oils are from Cambrian rocks.

Californian Petroleum.—The crude petroleum from Pico Cañon, Los Angelos county, is viscid and of a dark-green colour. Its specific gravity is 0·8414. A preliminary examination by Mr. F. Lengfield and Mr. E. O'Neill ‡ shows that this oil contains parafins, naphthenes, and homologues of benzine. It is probably intermediate in character between Pennsylvanian and Russian petroleum.

* *The American Geologist*, vol. xi. p. 131.
† *Revista Minera, Metalurgica y de Ingenieria*, vol. xliv. p. 79.
‡ *American Chemical Journal*, vol. xv. pp. 19–21.

Grahamite in Texas.—Mr. E. T. Dumble * describes two occurrences of grahamite in Texas. The first of these is in Webb county, and is almost certainly in beds of Cretaceous age. It occurs as a thin seam, and as detached masses in a layer three to six inches in thickness when it is mixed with gypsum and sulphur. In Fayette county, the grahamite is found in the centre of a 6-inch bed of brown coal. These two samples showed on assay :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Total.
0·30	44·00	52·80	2·90	100·00
None	57·90	57·70	4·40	100·00

and on analysis :—

Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.	Ash.	Water.	Total.
78·65	7·50	0·15	5·08	5·42	2·90	0·30	100·00
76·19	6·61	0·39	5·15	7·45	4·21	...	100·00

Trinidad Asphalt.—A considerable amount of information on the characteristics of pitch from Trinidad has been given in a recent report † devoted to asphalts and cements. In the island two sorts of pitch are obtained, and are known as lake pitch and land pitch according to their origin. The pitch in the lake is not of uniform composition, its softness seeming to depend on the amount of gas it is capable of evolving. Up to the present time, rather more than a million tons have been removed from the lake, and the most reliable estimates place the lowering of the level at about a foot. Deposits of pitch are also found between the lake and the coast, a distance of about three-quarters of a mile. Several qualities of this pitch are worked, and as much as 10,000 tons per acre has been obtained. The pitch obtained from the land is generally poorer in bituminous matter, and decreases in value according to the amount of weathering and oxidation it has undergone. A large number of analyses are given, with the physical properties of the samples as regards their softening and flowing points and specific gravity. A consideration of these enable the lake or land origin of the samples to be determined, and the value for asphalting purposes can be settled.

Asphalt in Peru.—According to E. Haber,‡ the asphalt veins in the

* *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

† *Sixth Annual Report of the Inspector of Asphalt and Cements.* Washington, 1891–1892.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xl. pp. 214–215.

valley of Mantaro, near Sorao and Huari, are of great geological interest, and may eventually prove of economic importance. The chief exploratory workings have been made at the latter locality. The veins worked course from north-east to south-west, and have a dip of 85° to the north-west. They traverse horizontal beds of limestone of a yellowish grey colour. The vein is 5 to 6 feet in width. Both walls of the vein are covered with a thin hard layer of yellow clay, which in many places exhibits slickenside faces. The vein stuff fills the entire width of the fissure; and, when freshly brought from the mine, it has a shining appearance and resembles splint coal. On exposure to the atmosphere it soon loses its lustre and crumbles away.

The workings at present are on a small scale. Only four men are employed, the daily output being 5 to 6 tons.

Sumatra Petroleum.—Some tests, made by Mr. Leyden, on the Langkat oil of Sumatra, as compared with Russian and American oils, have recently been published.* The specific gravity of this oil at 15° C. is 0·799. It is colourless, and it has a good illuminating power. By distillation, 79·6 per cent. is obtained between 150° and 270°.

VI.—*NATURAL GAS.*

Origin of Natural Gas.—The various theories of the origin of oil and natural gas are shortly discussed by Mr. J. Young.† The theory of origin by the interaction of water containing carbonic acid and fused metals is chemically perfect, but is not generally accepted by geologists, and the facts point rather to one of the theories depending on distillation or on primary decomposition as being the true explanation. Simple or fractional distillation explains many of the facts, but it has been shown that in some cases at least the rocks from which the oil might have been derived show no signs of metamorphism. Primary decomposition, on the other hand, can be observed at the present day in Trinidad, where recent beds of shale yield petroleum and asphalt. The author, however, considers that both of these theories merge into one another, and that the difference of distillation and decomposition is merely one of degree.

* *Board of Trade Journal*, vol. xiv. pp. 349–350.

† Lecture before the Western University of Pennsylvania, through the *Colliery Guardian*, vol. lxv. p. 634.

Other geological features are then dealt with, and also the chemical composition of the gas. The heating power of the gas is discussed, and the statistics of its use in the United States are given.

The Ignition of Natural Gas.—Mr. G. L. Cabot* states that natural gas, such as that found in Western Pennsylvania, is not ignited by contact with finely divided platinum, nor by an electric gas igniter. The temperature of ignition is much higher than for coal-gas. On the gas-pipe lines in cold weather it is necessary to keep gas fires burning along them to prevent them choking by frost. As these often become extinguished accidentally, it was suggested that platinised asbestos might be used to re-ignite them, but this it was found not to do, so that artificial gas had to be used for the re-igniting jet.

Natural Gas in Ontario.—In Ontario there are two natural gas fields, both on the north shore of Lake Erie, but separated from each other by a distance of 150 miles. Excepting wood, petroleum, and peat, gas is the only natural fuel in Ontario, and the question of economising and properly applying the supply is deserving of the most careful consideration. Mr. A. Blue† has consequently drawn up an exhaustive report on the origin, occurrence, and value of natural gas.

The Essex County gas-field in Ontario owes its development to the discovery of gas about three years earlier in Hancock County in Ohio. Encouraged by the success of borings on the Cincinnati Arch at Finlay in Ohio, local capitalists explored the country over the continuation of the Arch on the north shore of Lake Erie, the first test-well being put down at Kingsville in 1888. At the present time the gas is wastefully used by consumers. The experience of gas-producing districts in Ohio, where like wastefulness was the rule a few years ago, should teach a lesson in the economic use of natural gas. It is an excellent fuel; but in the richest fields the supply has limits, and in the vicinity of Kingsville the area, as far as proved, is greatly circumscribed.

Discoveries of Natural Gas.—Natural gas has been found at a well in Sandy Creek, New York, in such quantity that the noise of the escaping gas could be heard at a distance of two miles. Gas has also been struck at Willett, Indiana County, Pennsylvania, in the Big Injun sand, at a depth of 1100 feet. A new gas-field has been found in the

* *Journal of the Society of Chemical Industry*, vol. xi. p. 801.

† *First Report of the Bureau of Mines of Ontario*, pp. 115–164. Toronto, 1892.

neighbourhood of Cambridge, Ohio.* Gas has been struck in the Murrysville sand, to the south-west of Milltown, Pennsylvania, and a large supply has been obtained by a new well in Clarion County. A new gas-well, stated to have an outflow of 10,000,000 cubic feet of gas a day, has been drilled at Ruthven, Ontario.

Natural Gas in Indiana.—The natural gas-field of Indiana is the largest known. It covers an area of about 2600 square miles. The wells in this field are usually carefully husbanded, the gas being used sparingly and as required. The consequence is shown in the case of some wells at Muncie. Here three wells have been carefully watched during the two years they have been used by a nail-works, with the result that one well now shows the original rock-pressure, while the second actually possesses an increased pressure of 5 lbs., and the third an increase of as much as 15 lbs.†

Natural Gas in Ohio.—Professor E. Orton‡ considers the occurrence of natural gas in Ohio at some length. He refers to the formation in which the gas is found, and observes that the Clinton gas-field extends in a north-easterly direction for a distance of twenty-five miles, with a maximum breadth of two or three miles. The highest rock-pressure reported in this field has been 800 lbs. to the square inch. In the volume of gas yielded by the various wells there has been a very wide range. None have yielded less than 100,000 cubic feet a day; but in the neighbourhood of Lancaster the larger wells have yielded as much as 7,000,000 or 8,000,000 feet a day. In the Thurston field the usual range is from 2,000,000 to 5,000,000 cubic feet a day. The gas is superior in quality to that derived from the Trenton limestone, especially on account of the smaller percentage of sulphur compounds that it contains. It is also a better luminant. The central part of the Clinton field, in the vicinity of Thurston, is covered with heavy beds of drift, sometimes 300 feet in thickness. In the wells at this point the gas is struck at a depth of 2200 feet. At Lancaster, at one end of the field, the gas is found at a depth of 2000 feet, and at Newark, at the other end of the field, at a depth of 2400 feet. Salt water is met with in quantity in drilling wells in this field, except at its central portion. The Clinton rock is very broken and irregular, and oil occurs in but very small quantity.

* *American Manufacturer*, vol. lii. pp. 63, 461, 549, and 767.
† *Iron Age*, vol. l. p. 724.
‡ *American Manufacturer*, vol. lii. Nos. 6 and 7.

The Trenton limestone is the great source of gas in Ohio. All the oil-rocks and gas-rocks previously known were sandstones, but the Findlay gas-rock is a magnesian limestone of exceptional purity. The author observes that towards the close of 1889 he published an estimate of the probable duration of the gas-supply of North-Western Ohio; but that short as was the time he mentioned then, it was too long; and he now considers that not a single gas-line will be in effective operation in the winter of 1894.

It is stated * that the natural gas-supply of Ohio is failing rapidly. There has been a remarkable decrease in both the pressure and the volume of gas from the wells during the past year. Competent estimates place the duration of this gas-field at about fifteen years, provided the gas is carefully used. Owing to the failure in the pressure of the gas, gas-pumps have been erected on a large scale. One of these pumping plants deals with the produce of 300 wells, and another with that of 42 wells. Originally, the average rock-pressure of the gas was 350 lbs. per square inch, while in some instances it amounted to 500 lbs. and more. Four years ago it had fallen to 250 lbs., three years ago to 180 lbs., two years ago to 130 lbs., while in 1892 few tests showed more than 100 lbs., and 75 lbs. probably represented a pressure above the average.

VII.—*ARTIFICIAL GAS.*

The Composition of Coal-Gas.—H. Bunte † gives the following analysis by weight of the gas obtained from the distillation of a coal 100 parts of which yielded 17·04 of gas, 5 of tar, and 11 of gas-water:—

H.	CH_4.	CO.	C_nH_{2n+2}.	C_nH_n.	CO_2.	N.
7·4	42·8	19·9	8·4	7·4	8·6	5·5

On the distillation of such a coal as the above, about ten times the quantity of naphthalene is formed that can be taken up by the gas produced, one cubic metre of which at 15° C. can take up one gramme of the naphthalene. Consequently, coal-gas is always saturated with naphthalene, which it deposits if the gas is cooled, thus leading to a choking of the pipes through which the gas is passed. It is otherwise with the benzene, also produced in the distillation of coal in a closed retort. Of

* *American Manufacturer*, vol. lii. No. 5.
† *Journal für Gasbeleuchtung*, vol. xxxv. p. 569.

the total quantity produced, 93 per cent. was in the gas, and only 7 per cent. in the tar in the case the author quotes. Still, the gas was not saturated with benzene and toluol. Indeed, it only contained 4 per cent. of the quantity which would be required to effect the saturation; consequently, any cooling influence to which the gas may be subjected is not likely to seriously affect the percentage of benzene which it contains; and the author considers that, in order to avoid the difficulties which so often result from the deposition of naphthalene in the pipes, the gas should be thoroughly cooled in the first instance.

The Manufacture of Gas.—A. Henin* discusses the production of heating gas and ammonia from coal in the producer, and points out that the main conditions of the formation of ammonia are also favourable for the production of a good heating gas. High temperature, however, is not compatible with a large excess of steam, unless the latter is highly super-heated, or unless air is also admitted. The author finds that with the steam moderately super-heated and evenly distributed, a limited supply of air will maintain the temperature sufficient to allow the admittance of 1 to 1¼ lb. of high-pressure steam to the pound of coal. Under these circumstances 50 to 60 per cent. of the nitrogen in the coal is transformed into ammonia, and the composition of the gas is as follows:—

CO_2.	O.	CO	Methane, &c.	H.	N.	Total.
10·50	1·00	20·00	4·50	38·00	26·00	100·00

When the gas is quickly drawn off, the reactions seem to be facilitated by the partial vacuum, the ammonia is not dissociated, and the temperature is easily maintained. Each ton of coal will yield from 70 to 80 lbs. of ammonium sulphate, 130,000 to 150,000 cubic feet of gas, and 15 to 20 gallons of tar. To remove the ammonia without unduly moistening the gas, it should be well cooled before it is passed through the scrubbers.

Some experiments have been carried out at the Mitchell Main Colliery, near Burnsley, on the utilisation of shale for the manufacture of water-gas. The trials appear to have been successful.†

* *Chemical Trade Journal*, vol. xi. pp. 147–148.
† *Colliery Guardian*, vol. lxv. p. 715.

VIII.—*COAL-MINING.*

Shaft-Sinking.—Mr. F. Flint* describes the trial-sinking at the Old Roundwood Colliery, Wakefield. At a depth of 90 yards the Flockton thick coal had been cut by a boring, and much gas and a little water had been given off. When the sinking reached 60 yards, gas began to come off, and as the shaft was deepened the gas increased and presently filled the working. With some trouble the water which accompanied the gas was wound out and the sinking proceeded with, gelignite fired by electricity being used instead of powder. Walling was put in to keep out the gas, which was led off by means of pipes, and used in the ventilating furnace and elsewhere. Details of the pipes used for drawing off the gas and for ventilation are given.

An account of the sinking of the Maple Hill Shaft, near Shenandoah, Pennsylvania, is given by Mr. H. W. Althouse,† together with full details of the timbering employed. The shaft consists of two hoistways and one water compartment, each 7 feet by 11½ feet inside, and is timbered in sets throughout its depth of 754 feet with 12-inch square pine and backed with 3 by 2 inch planking. At the top, a masonry foundation, 20 feet high and 4 feet thick, was put in. During the sinking water was abundant, and was drained off by a central bore-hole sunk to meet a drainage tunnel from adjacent workings.

Mr. J. Tonge ‡ describes the work of deepening a shaft at the Hutton Colliery, where winding was carried on by day and the sinking at night. The pit was deepened from 140 to about 200 yards and was 12 feet in diameter. The cages were two in number, each carrying two tubs and having two guides diagonally placed. During sinking the cages were kept on the ropes, and an extra length of rope attached below one of them. By the aid of this the dirt was wound on one side of the pit only in hoppits up to the yard seam at a depth of 140 yards, where it was loaded into tubs which were stored in the level and afterwards wound.

Some dimensioned sketches of tubbing for a 13-foot and a 15-foot shaft have recently been published.§

* Paper read before the National Association of Colliery Managers, Yorkshire Section, November 26, 1892.

† *Journal of the Illinois Mining Institute*, vol. i. pp. 174–180, with three plates.

‡ *Transactions of the Manchester Geological Society*, vol. xxii. pp. 216–221.

§ *The Practical Engineer*, vol. vii. pp. 207–208.

Shaft-Sinking through Quicksand.—A modification of the Poetsch system of sinking through quicksand has been devised, and is described by A. Gobet.* Instead of circulating brine through the freezing pipes, liquid ammonia is introduced into them directly, and by its evaporation produces the necessary cold. The gaseous ammonia is drawn off and liquefied in compressing apparatus. A special form of joint is used for the pipes.

The Use of Cement in Shaft-Sinking.—In a paper read before the North of England Institute of Mining Engineers, Mr. Bennett H. Brough† pointed out the advantages of using cement in place of cast-iron and timber for lining shafts. It neither corrodes nor decays; its strength increases with age, and it is not appreciably subject to contraction and expansion. A recent application is the use of tubbing made of cement blocks for stopping back large quantities of water. The cement blocks are so shaped that they can be made perfectly water-tight. Their height is from 30 to 40 inches, and weight from 1543 to 1763 lbs. This method has been successfully applied at the Cecilia ventilating shaft of the Serlo Colliery, near Saarbrück. The shaft is 9 feet 10 inches in internal diameter, and the cement segments employed measured 15·75 inches in thickness, and 23·62 inches in height and in length. The tubbing of a shaft 500 yards in depth and 17 feet 2½ inches in diameter at the potash-salt mines of Leopoldshall, near Stassfurt, Prussian Saxony, was constructed in this manner, in order to prevent the admission of the enormous volumes of water met with in the saliferous strata. Several shafts in the Saar coalfield have also been lined on this system. The cost appears to be considerably less than that of the ordinary brick or iron tubbing, as shown by comparing the cost of tubbing a shaft 17 feet 2½ inches in diameter, where large quantities of water had to be dealt with. At the prices current in Germany the cost of this would be as follows:—

	£	s.	d.	
1. Iron	93	16	2	per yard.
2. Brick	114	5	5	,,
3. Cement	28	12	4	,,

The process not having been in use for any length of time, the writer is unable to give any data as to the durability of cement tubbing; but, so far, the tubbing put in has acted satisfactorily.

* *Colliery Guardian*, vol. lxiv. p. 1205, vol. lxv. p. 624.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 343–347.

Devices for Preventing Overwinding.—Mr. M. Walton Brown * describes an apparatus for cutting off steam and applying the brakes automatically, devised by E. Reumeaux, and in use at one of the Lens collieries in France. The throttle-valve in the main steam-pipe is placed between two steam-cylinders which are in connection with the pipe by small passages. A tappet on the tell-tale at the required point opens a valve and allows one of these cylinders to break off, so that the other closes the valve. A second tappet repeats the action when the cage reaches the bank, in case the first one failed, and then a third tappet exhausts the steam from behind the brake engine valve. The motion of this valve causes the second cylinder to exhaust, so that the throttle-valve is then freed. When the cage is near the bottom it strikes a tappet and opens the steam supply to the brake engines. A reservoir of steam or compressed air is provided against possible breakage of the steam-pipe.

A. Kas † states that Fröbel's safety catch is designed to prevent overwinding by stopping the engine automatically when at any speed, the break being put on and the steam at the same time shut off. Drawings accompany the description of the appliance, which is one of considerable simplicity.

Winding Engines.—Some notes on the construction and use of direct acting winding engines are given by Mr. B. W. Cooper,‡ with particular reference to those of a special make.

Mr. J. Hodgson § describes the partial collapse of a winding-drum which had recently been relined with oak timbers, 12 by 6 inches, and $4\frac{3}{8}$ feet long. The breakage of the lining is ascribed to the accumulated pressure due to the coils under a load of five tons. Mr. J. J. Prest pointed out that the drum would be polygonal with timbers 12 inches broad, so that the load would come on the corners.

An illustrated specification has recently been published ‖ for a 15-foot winding-pulley for $1\frac{1}{4}$-inch round wire rope. It is bored for a 7-inch shaft with two keyways. The bosses have wrought iron hoops shrunk on. The shaft is $4\frac{1}{2}$ feet long, with journals 5 inches in diameter and 10 inches long.

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 1026-1027, with plate.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 603-604, with plate.

‡ *Journal of the Illinois Mining Institute*, vol. i. pp. 145-153.

§ *Transactions of the National Association of Colliery Managers*, vol. iv. pp. 378-380.

‖ *The Practical Engineer*, vol. vii. p. 102.

Another specification * gives the dimensions of a wrought iron headgear recently constructed. It is 46 feet high to the pulley centres, the main legs are 44⅞ feet long, the backstays 71⅛ feet. It is built up of lattice-work and angle iron, the dimensions being fully given.

Self-Acting Inclines.—The several methods of working self-acting inclines on steeply-inclined seams by means of a counterbalance and a carriage on which the tub is placed, are discussed by Messrs. D. M. D. Stuart and J. Sparkes,† and a description is given of a special arrangement for this purpose which has been at work for the past twelve months in the Bristol coalfield. The counterbalance has been used on a line of rails at one side of the main track, but then the coal on one side of the road is not easily worked. In several instances the counterbalance track is placed between the lines of rails on which the carriage runs. This necessitates that the carriage should be built high enough to let the counterbalance pass underneath, or else that the outer rails should be raised or the inner ones lowered, or both, either over the whole track or at the passing places only. In the latter case, the change of gradient is more or less abrupt, and in either case there is difficulty in laying the rails with transverse sleepers. In the particular form of carriage described by the authors, there are four equal-sized wheels, and the tub is carried by a horizontal platform, which is supported on the axles by a built-up triangular iron framework strengthened by angle pieces at the corners. The framework is so designed that the angles can be adjusted to keep the platform level. Further, the axles are cranked to allow room for the counterbalance to pass underneath. This counterbalance consists of a simple frame on wheels, with a number of weights in the form of iron bars, that can readily be removed or replaced to adjust the weight.

Mr. S. Alsop ‡ gives a description of a self-acting endless chain used for lowering the tubs from one seam to the pit-bottom, 50 feet below. A stone drift with a gradient of 1 in 3 is used, and the chain is made of riveted links, two 6 inches long and then one of 12 inches, working round a hexagonal drum. Pegs or sprockle links are put in every 42 feet to hold the tubs. The chain runs at about 1½ mile per hour, lowering the full tubs and lifting the empty ones. It is 340 feet long,

* *The Practical Engineer*, vol. vii. pp. 170–172.

† Paper read before the National Association of Colliery Managers, March 28, 1893, *Colliery Manager*, vol. ix. pp. 64–65. Patent No. 675, 1892.

‡ *Transactions of the National Association of Colliery Managers*, January 14; *Colliery Manager*, vol. ix. p. 6.

and the cost of chains and pulleys was about £30, cost of labour and materials being about 1s. 8d. per ton.

Some clips for coupling the rope in rising stalls, where the rope has to be lengthened as the stall advances, are described by Larmoyeux.* In one form the rope is passed through a hollow cylinder and held by a pressing piece and three screws. In another form the clip is made in two parts drawn together by bolts. In each case the clip ends in a loop or ring for attaching the chains on the tubs.

Underground Haulage.—A full description is given by Mr. W. E. Garforth † of the underground chain haulage systems at the West Riding Collieries, Normanton, in the Stanley and Haigh Moor seams, and in the Silkstone seam. In the Stanley seam an endless chain haulage has been in use for about twenty-six years. A horizontal engine, 40 yards from the shaft, with one cylinder 3 by 1½ feet, geared in the proportion of 4 to 1, drives a 4-foot chain drum. The chain is made from ¾-inch full round iron, and will bear a working load of 7 tons. It passes 2½ times round the drum, and travels at 2 to 3½ miles per hour, being placed over the tubs. Details of the length of the road and its inclinations are fully given. In addition to the chain haulage there is also a main and tail rope system. If the chain breaks, a piece 25 yards long is inserted at the break, the empty side is made fast and the full side drawn in by the engine, when the excess chain is cut out of the slack. Particulars are also given of the chain haulage in the Silkstone seam. Automatic greasers and electric signals are used throughout. Some account of chain tests is appended, to show the strength, elongation, and wear of the chains in use, and the results point to the desirability of having the chain as large and strong as possible, compatible with the extra weight, working round small drums. The metal should have a certain degree of hardness, or else the links wear into each other.

The endless rope haulage at the Thorncliffe, Rockingham, and Tankersley collieries are described by Mr. W. H. Chambers.‡ The plant at work is shown by the following table :—

* *Bulletin de l'Association des Ingénieurs sortis de l'Ecole de Liége*, 1893, pp 40-42.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 960-969, with two plates.

‡ *Ibid.*, pp. 970-979, with plate.

Name of Colliery.	No.	Cylinders.		Engine.	Length of Ropes.
		Diameter.	Stroke.		
		Inches.	Inches.	Geared at	Yards.
Drift Pit	2	22	55	8 to 1	13,712
Norfolk Pit	2	15	30	8 to 1	9,100
Smithy Wood	2	14	16	8 to 1	2,000
Tankersley	2	14	16	26 to 1	10,550
Rockingham	2	16	24	8 to 1	9,080

In the Tankersley Colliery the full tubs are put on in sets of two, and empty tubs in sets of four. Details are given of the various sections, and the cost and advantages of the system are dealt with.

Mr. W. Rutledge * describes the system of endless rope haulage which is used in three or four of the Illinois collieries. Two trucks are usually employed with one endless rope, which is taken up the entries and back into the main road. The engines are placed underground some 100 feet from the shaft, and are worked by steam from the surface; but it would be better to use electric transmission of power. The rope runs at 200 to 300 feet per minute, and hauls the tubs in trains of an average number of ten tubs. The grip used is that devised by Mr. J. E. Curr; it has a fixed lower jaw and a vertically sliding upper one, depressed by a cam ended lever. At No. 1 Colliery, Pana, the rope has a length of 10,000 feet, and the coal wound from this shaft is 1000 tons. At the Lincoln Colliery the rope is 8300 feet long, and will be extended 4000 feet. It is capable of hauling 2000 tons of coal.

Mr. W. Hargreaves † describes some systems of underground haulage at Messrs. Charlesworth's collieries. Of the twenty separate haulages in operation, eighteen are worked by engines at the surface and two by underground engines. There are nine main and tail ropes, six main ropes, and five endless ropes, about forty miles of rope being employed. At the Rothwell Haigh collieries five corves are mounted on a trolley, two of which make a set. In the tail rope system, at the Robin Hood collieries, the inner rail is super-elevated on the curves, a special form of clipper is used for connecting the branch ropes, and the haulage pulleys are moved forward twice a year as the face advances, so that no horses are employed. An over-rope system is also used in this colliery. Particulars are also given of the several haulages at the Thrybergh Hall Colliery. The cost of some of the various systems is stated.

* *Journal of the Illinois Mining Institute*, vol. i. pp. 88–99, with four plates.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 294-303.

In the place of the older form of chain-haulage, rope-haulage has been largely introduced in Germany. Messrs. Cremer* of Hörde, in Westphalia, are erecting a haulage system of this kind, in which the rope passes on rollers below the waggons. It is some 2700 yards in length and has a capacity of 100 tons per hour. The cost is placed at £1750, the rope costing £225, and the rest of the plant the remainder. Placing the life of the rope at a year, and allowing 16 per cent. for the wear and tear of the rest of the plant, the cost of haulage will be found to be about a halfpenny per ton per mile, as compared with threepence when horses are employed.

Mr. W. Weston† describes a simple form of rope clip, and an automatic detacher used in connection with it. The clip consists of an L-shaped upper jaw, which is passed over the rope with a slightly excentric jaw pivoted to it. The tub is attached by a chain and swivel link to the tail end of the pivoted jaw. For detaching, the rope runs through a staple which catches the upper end of the pivoted jaw and loosens the grip; at the same time the chain is unhooked from the tub and the clip taken off the rope by a boy. The tubs are attached in pairs 50 yards apart.

Electric Haulage.—A complete description is given by M. Georgi‡ of the electric locomotive system of haulage, which has been in use at the Zauckerode Colliery since 1882. The line is double, 2460 feet long, with a curve of 59½ feet radius on some 160 feet, and it lies at a depth of 720 feet. A new type of locomotive was introduced in 1891, which gave an efficiency of 56 per cent., as compared with 41 per cent. obtained from the old locomotives. The cost of haulage is 0·35d. per truck hauled a distance of 820 yards. The cost of the locomotive is £350, and of the rest of the plant £5500, and as the original locomotive has lasted ten years, interest and depreciation are allowed at the rate of 15 and 10 per cent. on the locomotive and plant respectively. The loaded truck holds 0·45 ton, so that the cost per ton-mile is 1·6d. With horse-haulage on this line to give the same output, the cost would be about 0·5d., taking five horses with their ostlers at a cost of 32s. 6d. per day as being necessary. The saving as compared with horse-haulage thus amounts to £150 per year.

Electric chain-haulage was put down in 1890. The motor runs at

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 48.

† *Transactions of the National Association of Colliery Managers*, vol. iv. pp. 373-375, with illustration.

‡ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1892, p. 40.

1150 revolutions per minute, and drives the chain at a rate of 2¼ miles per hour. It is supplied with current from a dynamo giving 20 amperes at 410 volts when running at 880 revolutions. The efficiency is 85 per cent., rising to 88·8 per cent. with a maximum load, or 65·4 and 68 per cent. respectively of the work done by the engine driving the dynamo. The cost of the engine, dynamo, and house was £359, of the electric plant underground also £359, and of the haulage plant, including the chain, £237. The costs by the two systems may be tabulated as follows :—

Description.	Cost per Truck.		Cost per Annual Output of 800 Trucks Daily.	
	Locomotive.	Chain.	Locomotive.	Chain.
	d.	*d.*	£	£
Steam	0·056	0·062	54	38
Labour	0·141	0·312	135	187
Lubricant and repairs . .	0·038	0·075	36	45
Interest and depreciation of plant	0·112	0·175	108	107
Totals . . .	0·347	0·624	333	377

The choice between these two methods is determined by local conditions, but probably the locomotive is most suited for small and medium outputs and distances, and they may often replace horses with advantage.

An illustration is given * of an electric locomotive for a track of 30-inch gauge. It is 9½ feet long, 3 feet wide, and 4½ feet high. The wheels are 2⅓ feet in diameter, and the wheel base is 3⅓ feet long. Each axle is driven by its own motor. The trolley pole can be placed on either side, and is insulated. Similar locomotives to these are at work, and a few particulars have been given. A 48-horse power locomotive on an incline of 2½ per cent. in favour of the load, and about a mile long, delivers 500 trucks from four working openings. A truck fitted with two 6-horse power motors takes about 200 trucks per day from the miners, an average distance of 2000 feet, and forms them into trains.

An illustration is given † of a mining locomotive, designed to meet the demand for a small and substantial machine. It has two motors, and is so arranged that it can easily be taken to pieces. For gauges narrower than three feet, four-pole motors are used.

* *Engineering News*, vol. xxix. pp. 60, 117.

† *Engineering and Mining Journal*, vol. liv. p. 583.

In a paper on the applications of electricity in bituminous coal-mining, Mr. E. A. Sperry * describes the electric locomotives designed by himself, and in use in several States on gradients as high as seven per cent. Three sizes, weighing 8, 10, and 12 tons, have been built; the motor of the largest size is of 125 horse-power capacity, and 250 volts is the highest pressure that has been used. Each locomotive has eight drivers grouped in two bogies, and all the drivers are driven from the same motor, a form of universal joint in the spur-driving gear being used to allow of this being done. The rails used have not exceeded in weight 20 lbs. per yard. The conductor is carried by elastic supports, so that the collecting trolley runs steadily on it without jumping.

Wire Ropeways.—Drawings have been published illustrating the Bleichert system of wire ropeways. In this system separate stationary cables are employed, on which run carriages supporting the buckets, the motive power being transmitted through a light, endless, moving rope.†

Colliery Sleepers.—Illustrations have been published of a method of using worn rails as sleepers, devised by Mr. J. W. White.‡ Old rails of channel section are provided with clips which are riveted in the groove and hold the rails. When old colliery six-foot rails are employed, they are cut in two to form two sleepers.

The Preservation of Mine Timber.—Potassium orthodinitro-cresol, known by its commercial name as antinnonin, is stated to possess a remarkable destructive power for all kinds of lower vegetable organisms. In this respect its action in preserving mine timbers from dry-rot is important.§

The Substitution of Steel and Iron for Timber in Mines.—Mr. J. Johnson ‖ describes his experience of the use of steel and iron

* *Transactions of the Amerian Institute of Electrical Engineers*, vol. ix. pp. 375–406, with illustrations; *Journal of the Illinois Mining Institute*, vol. i. pp. 47–82, with illustrations.

† *Iron Age*, vol. l. p. 568, 16 illustrations.

‡ *Industries*, vol. xiii. p. 653; *Iron and Coal Trades Review*, vol. 1893, p. 109; *Colliery Guardian*, vol. lxiv. p. 1217.

§ *Suddeutsche Bauzeitung*, 1892, No. 60, through *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 168.

‖ *Transactions of the Manchester Geological Society*, vol. xxii. pp. 145–149.

instead of timber for mining purposes. Some six years ago he secured 300 yards of a main road, 10 feet wide, by iron props and steel girders placed 3 feet apart and covered with ⅜-inch boiler plate. Not one girder had been replaced, and he now has 1400 yards of main road secured in this way. The girders used are 10 feet long and 5 by 4 by ⅜ inch in section, and the props are 6 feet long and 5 by 3 by ⅜ inch in section. Thirty square feet of ⅜-inch boiler-plate is also used. The cost per yard run is 31s., and that of timber is 10s. to 12s. The cost is thus three times that of timber, but the life is six times longer, there is less risk, and no stoppage through falls. The material can be used again or sold as scrap, so that altogether the use of metal is greatly to be preferred. In the discussion, Mr. H. Hall agreed with the author when there was no moving weight, but in that case he thought timber preferable. Mr. W. Saint referred to the difficulty of removing the girders when affected by moving weights and side pressure.

Underground Pinning or Stowing.—Mr. W. Griffiths * gives some notes on underground pinning or stowing, to which such careful attention is required, especially in the long-wall workings in the South Wales district. Some of the steam-coal seams in this district have a strong roof, and do not require such careful stowing, but, as a rule, it is necessary. When the packing is neglected, the coal at the face is crushed, the roof is broken, and gas is liberated to a large extent. The effect of pressure on the main roads where pinning has been neglected is speedily seen in the difficulty of keeping them open. The roof is crushed and tends to run, so that much waste material has to be removed under the most dangerous conditions to reopen the road, and the hollow spaces that are left are always a source of trouble. At some collieries, when driving winning headings, the practice is to drive three abreast with a face of 40 to 50 yards, and give a large area of gob as the face advances, so that the top settles evenly. The breakages are further from the chief or middle heading, which is kept strong by a firm gob on each side of it. A plan is also adopted of driving the engine roads through gob packed about two years behind the face. When winning headings have to be driven quickly to gain coal without a gob on one side, the coal should be worked off quickly on that side to get room for the packing. At the face much time is often wasted in timbering when it would be far preferable to spend the time in putting in packs. The method of building these is given in some detail.

* *Colliery Guardian*, vol. lxiv. pp. 838-839, with illustrations.

The Roofs in the Rhondda Valley Seams.—A careful and detailed description is given by Mr. D. Hannah * of the roofs of some of the principal seams of coal in the Rhondda valleys and of the methods of treating them. The roofs selected are those of the two feet mine, four feet and six feet seams. They consist of alternating layers of fine grained compact shales or "clifts," hard compact arenaceous shales or "quarr," layers of ironstone nodules, carbonaceous shales and mixtures of fireclay and shale known as "bastard fireclay." These beds are of various thickness and character, but are conformable to each other. The occurrence in each of the seams mentioned above is then given in detail, with the methods of working and supporting the roofs. The effects of faults, both small and large, rolls, undulations, and overlappings are then considered. As a rule, the depth does not affect the roof to any extent. Gobbing should be thoroughly done and kept close to the face. Pillars should not be left, but a continuous face should be maintained and carried forward regularly. Tender roofs should be propped with light timbers, but heavier props are used under stronger roofs. It is advantageous to raise the roads above the gobs unless there is a weak roof that widens upwards, in which case side walls, logs, or masonry are substituted for timbering. Arching the roof, if possible, is preferable to timbering. The least objectionable disturbances are clean faults, even if the throw is considerable.

A Threefold Long-Wall Working.—Mr. D. Smith † gives an account of a threefold long-wall working at the Jelliestone Collieries, Dalmellington, where there are three separate seams of coal too far apart to be worked as one, and closer together than is usually convenient to work together. A level is driven in the top coal, and cross cuts are driven on the rise side into the lower coal, where a level is driven and the coal worked long-wall to the rise. When the lower coal in the section is exhausted, the mid-coal is pierced up into from the second level in the lower coal, and this coal is also worked long-wall to the rise as far as the lower coal has been worked, the same roads being used. At the extreme end the working of the upper coal is then commenced, and a long-wall face is carried backwards to the level.

The Use of Explosives in Mines.—The employment of explosives in coal-mines is dealt with in some recent articles in *Arms and Ex-*

* *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 177-199, with illustrations.

† *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 113-114, with plate.

*plosives.** The danger of firing the gas, the weight of the explosive to be used, testing explosives, the recently used high explosives and electric firing are discussed. An account of experiments made by H. Lohman and others is also given.

A review of the literature of explosives, as far as their safety in coal-mines is concerned, is given by Mr. E. Gilpin,† with a view of determining the limits of their use in Nova Scotia.

Mr. H. S. Poole ‡ gives an account of the use in Nova Scotia of of roburite and acadine. At first considerable trouble was experienced with roburite, as the men were unaccustomed to its use, but this has now been overcome. About 7300 lbs. have been used, and the number of times that flame has been observed is small. In four instances the roburite burnt in the hole instead of being exploded by the detonator. It is found to be about 2½ times stronger than gunpowder. Acadine is not much used except in Nova Scotia. It consists of a mixture of ammonium nitrate, and nitro-glycerine. Care has always been taken to use it soon after manufacture. It is about 50 per cent. stronger than gunpowder. During the use of 6400 lbs., light has only once been observed.

The Combustion of Gunpowder.—H. Debus § discusses the chemical theory relating to powder. He points out that the quantitative composition of powder varies within certain limits. The oxygen of the impure carbon during the combustion of powder escapes in combination with hydrogen as water, and the chemical theory of the explosion of powder relates only to the reactions which occur between nitre, pure carbon, and sulphur. The products resulting from the combustion of the powder are the potassium salts, carbonate, sulphate, and sulphide, carbonic anhydride, carbonic oxide, and nitrogen. The potassium sulphide is the bisulphide, and not the monosulphide. The relative quantities of these combustion products are dependent on the composition of the powder, and not on the pressure which existed at the time of the combustion. The carbonic oxide may be considered as the result of a secondary reduction of carbonic anhydride by an excess of carbon present or by potassium sulphide. The author gives the following chemical equations with a view to show the ways in which the chief products of the combustion are formed :—

* *Arms and Explosives*, vol. i. pp. 31-34, 61, 62, 68, 103.
† *Transactions of the Canadian Society of Civil Engineers*, vol. vi. pp. 57-68.
‡ Paper read before the Mining Society of Nova Scotia.
§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 36.

$$a.\ 4\,KNO_3 + 5\,C = 2\,K_2CO_3 + 3\,CO_2 + 2\,N_2$$
$$b.\ 2\,KNO_3 + 1\,C + 1\,S = K_2SO_4 + CO_2 + N_2$$
$$c.\ 2\,KNO_3 + 3\,C + 2\,S = K_2S_2 + 3\,CO_2 + N_2$$

All black powders may be considered as mixtures of *a.* *b.* and *c.* in different proportions, and their combustion as the product of the products of the combustion of each of these three burnt separately; *a.* yields the greatest amount of energy, *b.* the greatest heat, and *c.* the largest quantity of gas. The reaction *c.* is in reality much more complicated than would appear to be the case from the above equation. Some kinds of powder contain only two of the above three "mixtures." The brown Westphalian powder, consisting of $2a + b$, whilst the blasting powder in general use in France, consists of *c.* alone. The true explosion is a result of the combustions *a.* and *b.* The equations, *a.* *b.* and *c.* may be combined into one, from which the following equations for the gas volume, V, and the quantity of heat, W, may be deduced :—

$$V = \frac{160 + 20\,y + 16\,z}{14} \times 11{,}190 \quad . \quad . \quad . \quad (d)$$
$$W = 1{,}827{,}154 - 16925\,y - 8788\,z \quad . \quad . \quad . \quad (e)$$

The number found for V, assuming the weight of powder to be one gramme, shows the number of cubic centimetres of gas which that weight of the powder will yield, assuming it to consist of 16 molecules of nitre, y atoms of carbon and z atoms of sulphur; and similarly W gives the number of heat-units that a gramme of this powder will yield. The product of these two values is proportionate to the explosive power of the powder, and it is possible to calculate the relative powers of various powders directly from their composition. With the nitre and sulphur constant, an excess of carbon increases the power of the powder, and with constant nitre and carbon an increasing percentage of sulphur reduces it. The mixture *b.* is more sudden and violent in its action than is *a.*, and the same holds good as regards *b.* when compared with *c.*, although the actual total result is nearly identical with both mixtures.

Experiments with Favierite.—H. Ritter * gives the results of a series of experiments made in the experimental level of the Segengottes Colliery in Moravia with the explosive favierite. In this district the danger from coal-dust explosion is extreme, and the experiments, which the author describes, gave results which were of a most satisfactory

* *Oesterreichische Zeitschrift für Berg- un Hüttenwesen*, vol. xli. pp. 105-107 and 124-128.

character. Hitherto this explosive has been but little known in Austria. The explosive experimented with was made in Belgium. Favier powder No. 1 consists of 88 per cent. of ammonium nitrate and 12 per cent. of dinitronaphthalene packed into white cartridges. The anti-fire-damp favierite No. 2 consists of 90 per cent. of the No. 1 powder and 10 per cent. of ammonium chloride in red cartridges. Both these powders, but especially the latter, proved very safe in the presence both of fire-damp and of coal-dust. There are two other kinds which are not intended for use in the presence of fire-damp. These are the blue cartridges, containing a mixture consisting of 92 per cent. ammonium nitrate and 8 per cent. dinitronaphthalene; and Favier powder No. 4, composed of 95·5 per cent. ammonium nitrate and 4·5 per cent. of the dinitronapthalene. Only the two first of these were held to be of importance in the experiments, and the author describing them observes that the Favier cartridge can be safely subjected to all imaginable requirements; requirements, indeed, which can never occur in practice. The explosive does not freeze, and the only important objection which the author makes to it is that it requires a very strong detonator to effect its explosion. The explosive experiments are described in detail. The explosive No. 2 proved perfectly safe in the presence of the most dangerous mixtures of coal-dust and fire-damp; and with the explosive No. 1, out of the thirty-one experiments in which coal-dust was used alone, a partial ignition of the dust was observed in but a single instance, without any pronounced explosion; and in fourteen experiments with mixtures of fire-damp and coal-dust, not a single explosion took place; No. 3 explosive, on the other hand, produced, even with small charges, coal-dust explosions even when no fire-damp was present, and its use affords, therefore, no security. Compressed black powder, too, and No. 1 meganite always produced, even with small charges, explosions when present with Rossitz dust. The anti-firedamp favierite was found to be much safer than the other explosive of a similar name, grisoutite. This the author shows by a comparison of the results of numerous experiments made with the two explosives.

New Explosives.—A. Berg * and Cari-Mautrand observe that mixtures of hypophosphites with chlorates form explosives, the use of which would appear practicable. One part of barium hypophosphite mixed with one part of potassium chlorate, both dried in the first instance and powdered very fine, gives a compound that, when ignited in the air, burns

* *Bulletin de la Société Chimique*, 3rd Ser., vol. ix. p. 94.

rapidly with a slight explosion; but the least thing which may prevent the rapidity of the combustion causes the mixture to explode with a degree of violence similar to that of fulminate of mercury. A similarly powerful explosive results on admixture of powdered chlorate with a syruppy solution of sodium hypophosphite.

C. Istrati * gives the analysis of a smokeless powder, which left very little ash, was insoluble in water, and could be ignited without explosion. This powder the author found to consist of a mixture of 48 per cent. of nitro-glycerine with 51·5 per cent. of trinitro-cellulose, with 0·5 per cent. of resin as a protecting cover.

Mr. T. Johnson † describes some of the high explosives, especially ammonite. Some experiments to show the comparative power of these explosives, and of their power to resist concussion under falling weights, are given. The various advantages of ammonite are also described.

Shot-Firing.—With a view of ascertaining information as to present practice, Mr. H. Hall ‡ has started a discussion on the danger attending the recovery of missed shots. A second shot is often put in close to the first, but does not always succeed in exploding it, and several serious accidents have recently taken place in the attempt to subsequently pick out the unexploded cartridge from the solid coal. The danger seems to arise from the low temperature of explosion of the detonator and from the impatience of the collier. A rule should be made that only the fireman should recover the missed shot, and even he should not pick it out. There was no rule so often broken by the collier as that relating to unramming.

Mr. F. Brain § describes the several methods in use for electric shot-firing, including the low and high tension systems and the frictional and magneto-electric exploders. The low-tension fuse may be tested before firing, but as a rule the high-tension fuse meets all requirements, and the cost of both systems is about the same. The necessity of using electric firing is insisted upon, and the absurdity of using safety-lamps and ordinary fuse at the same time is pointed out. The advantage of simultaneous firing for several shots is mentioned, and the use in connection with this system of the electric light mains. A set of rules is

* *Bul. Soc. Sciinte Fizice din Bucuresci*, vol. i. p. 225; *Chemisches Repertorium*, vol. xvi. p. 377.

† *Transactions of the National Association of Colliery Managers*, Nov. 29; *Colliery Manager*, vol. ix. pp. 3–5.

‡ *Transactions of the Manchester Geological Society*, vol. xxii. pp. 151–158.

§ *Transactions of the National Association of Colliery Managers*, vol. iv. pp. 382–388.

appended dealing with charging, firing, faults, connecting, and general hints. Missfires with the high-tension system are often due to deterioration of the exploders, but this can be remedied by re-magnetising the magnets.

For extracting the tamping from a bore-hole after a missfire, it has been proposed by F. Kuhn to use an augur made of brass. In case of powder, the charge can be withdrawn if it is wetted; or if dynamite is used, a fresh charge is inserted a little way above the old one.*

Coal-Cutting Machinery.—According to the seventeenth annual report of the Chief Inspector of Mines for Ohio, Mr. R. M. Haseltine, only one mine has lately adopted coal-cutting machinery, while five mines have discontinued their use. Of these, three used electricity and two compressed air as motive power. Mining machinery is now used in 21 mines. Of these, 13 use compressed air, 6 electricity, and 2 use both as motive power; 1,654,081 tons, or a gain of 505,632 tons over the preceding year, was produced by these means, which gave employment to 900 hands. There are 114 machines in use, of which 25 are electric and 89 are driven by compressed air. Electric haulage is employed in two mines.

In a paper on electricity applied to the mining of bituminous coal, Mr. E. A. Sperry † describes the pick machine devised by himself. The special feature in this machine is the connection between the percussive part and the rotary driving gear, by which the tool in its forward blow is independent of the driving gear, but is reconnected immediately the blow is delivered. The effect of recoil is thus minimised, and the machine may be made much lighter. The tool is retracted against the spring that delivers the blow by means of a connecting rod and crank. This crank is connected by a spring to an arm, which is loose on the driving-wheel, and is connected to it by a pawl, which immediately falls into gear and transmits motion as soon as the return stroke commences, but rides loose on the forward stroke of the tool when the latter has a greater speed than the driving-wheel. The machine is carried on a two-wheeled truck. The tool has a stroke of 6½ to 7½ inches, and weighs from 100 to 150 lbs. The current required is about 10 ampères at 220 volts. A very large amount of work has been successfully performed with these machines. The author also describes an electric

* *Revue Universelle des Mines*, vol. xxi. pp. 334-335.

† *Transactions of the American Institute of Electrical Engineers*, vol. ix. pp. 375-406, with illustrations. *Journal of the Illinois Mining Institute*, vol. i. pp. 47-82, with illustrations.

rotary drill and a coal-cutting machine of the chain-cutter type, in which the cutter chain works like the wheel in a wheel-cutter type of machine. The disadvantages of some of the other forms of chain and bar machines are pointed out, and the non-success of solenoidal action is also referred to.

Mr. E. Scott* discusses the advantage of electric over compressed air and other systems for transmission of power in mines, the dangers incidental to the former method, and the constructional details of the plant. Various rotary and percussion drills are described, and also the different forms of coal-cutting machinery which are in use.

Mr. G. Richards† gives illustrated descriptions of some of the recently devised coal-cutting machines driven by electric motors. Amongst those shown are Sperry's pick machine, Atkinson's rotary bar-cutter machine, and Keil and Westerdahl's chain-cutter machine. Some electric percussive drills and sinking machines are also described.

Rock-Drills.—The Franke drill‡ has been used of late with satisfactory results in the Mansfeld district, and the Elliott drill has been largely and successfully employed at the Friedrichsthal Colliery, near Saarbrücken. This drill has driven from 15 to 18 yards per month, at a cost which is stated to have been 17s. per yard when power was used, or 70s. when the drill was run by hand. At another level this drill ran per month with power 17 yards and by hand 15 yards, the cost in each case being 45s. The England hand-drill has given good results in the soft clay slates of the Düren district, but the whole power of the drill was only utilised when two men were employed to turn it. Comparative results made between hand-labour and the Fröhlich-Jäger drill in shaft-sinking at the Grimberg iron ore mine, in the Siegen district, showed that by using the power-drill there was not only a saving of £7, 8s. per yard, but, at the same time, the progress made when using it was twice as rapid. The cost of the compressed air in sinking this shaft proved to be 28s. per yard, with a corresponding saving as compared with the cost in hand-boring of from 25 to 27 per cent. Schramm and Duisburg drills have been employed in the Diez district of Prussia. Three times the progress was made as compared with hand-drilling, but the cost was somewhat higher.

The Rearer Coals of North Staffordshire.—The methods of

* Paper read before the Yorkshire College Engineering Society.

† *La Lumière Electrique*, xlv. pp. 56-62.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xl. p. 423.

opening out and working the rearer coals of North Staffordshire are described by Mr. E. Craig.* These seams include those lying at angles between 45° and vertical, and are very numerous. They vary in thickness from 14 down to 4 feet, and the coal, the roof, and the floor vary through all degrees from good to bad. Seams at a less angle than 45° are not regarded as rearers at the present time, and are worked by ordinary methods. Rearers are opened out on the pillar and stall system. The pillars are exhausted from the rise downwards in breadths of 120 yards. A breadth is worked from vertical shafts through stone drifts from which levels are driven in the seam at the bottom of the breadth. Cage-dips are driven up from the level to within 10 yards of the top, and headings are put out on each side for a distance of 100 yards. The cage-dip, down which the coal is lowered, is laid with two lines of rails, and forms a self-acting incline, with a dummy or counterbalance on the inner and narrower line to haul up the empty cage and truck. The pillars are worked from the far end back to the cage-dip by means of shoulders from the bottom end. In the worked-out space the gob is formed, and on working out the next lower pillar, the gob is allowed to slide down to form a support for working on. The top workings are kept 12 to 15 yards in advance of the pillar below, and one dip will give about 120 tons per day.

Long-Wall in North Staffordshire.—The long-wall method of working in North Staffordshire, applied to seams varying in thickness from $2\frac{3}{4}$ to 8 feet, and in dip from 14° to 20°, with roofs of hard and soft "metal," is described by Mr. E. B. Wain.† This method has been carried on for some nine years at the Whitfield Colliery in five seams with unqualified success, both as regards safety and economy. The chief difficulties found were, first, the tendency of the roof to dip and sink away from the face, thus taking the working weight from the coal; and, second, the disturbance of the packs, &c., on the higher side of the level gateways, caused by the dipping of the roof. These difficulties are, however, overcome by paying careful attention to the packing and timbering and to the regular advance of the face. Special care is taken in building the first packs, and thus the opening-out stall is carried forward with a working face nearly in the line of full dip. In the thinner seams, ripping from the roof supplies material for the walls, which are kept in advance, and chocks are put in on the higher side of the road.

* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 48-52, with plate.

† *Ibid.*, pp. 24-35, with two plates.

In the thicker seams packing is done with stuff brought from other parts of the mine, and some coal is left in the roof to reduce the height necessary. Gate roads are laid out as nearly as possible at right angles to the face, so that the packing bears evenly under the roof, which breaks parallel to the face. The object in working is to keep the face constantly advancing, so as to regulate the pressure and to keep a "travelling" weight on the coal. Full details of the work and packing are given by the author, who also discusses the angle of the breaks in the various seams.

Working Adjacent Seams in the Saarbrücken Coalfield.—More frequently than in other mining districts, partings of sandstone and shale are met with in the Saarbrücken coalfield, swelling out rapidly from a few inches to several yards, whilst the thickness of the seam itself remains uniform for long distances. In consequence of this variability of the partings, the coal-seams, more especially in the eastern portions of the coalfield, are brought into such close proximity as to render the working difficult. The various methods of working in vogue in the district, and the attempts made to overcome the difficulties, are fully described by Dütting.* The methods used are the following:—

1. Working very thick seams. The seam is worked in slices from roof to floor, either by the pillar and stall method, or with filling in waste material.

2. Working seams with a parting of 3 to 6 feet. (*a.*) Pillar and stall method, in which the seams and the parting are worked away simultaneous, either from the roof to the floor or from the floor to the roof. (*b.*) Long-wall method, in which the seams and the parting are removed simultaneously, as in the preceding method, or the two seams are worked independently, but more or less simultaneously, the parting being left. (*c.*) Stopping method, in which the seams are worked simultaneously, and the parting left standing.

3. Working seams with a parting of more than 6 feet. The seams are worked by long-wall or by pillar and stall, the main roads being confined to one seam.

4. Working each seam independently. When the first seam has been completely worked out, and the subsidence has taken place, measures are taken to work the second one.

No general rule can be laid down to determine which of these methods

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xl. pp. 223–251.

should be used in a given case. Each method has advantages and disadvantages, and the choice must be determined by local conditions.

Sagged Coal.—Mr. J. Wyper* gives his experiences of what is known as sagged coal, and an explanation of its causes. Sagged, or bent, loaded, or overburdened coal is the result of working seams above or below. The coal is caused to become hard, the roof becomes loose, and the floor has a tendency to heave. From the experience gained in several localities, it would seem that sagging is more apparent in small than in large areas, and in deep than in shallow pits. When only a small area is worked, the roof breaks away in the form of an arch, but as the workings extend the arch falls in, and the whole ground, right up to the surface, breaks away and settles down uniformly.

Coal-Mining in Alabama.—Mr. R. Mauchline† describes the collieries and coke-ovens of the Mary Lee Coal Company at Lenisburg, near Birmingham, Alabama. At present the coal is worked by an incline; there are 110 coke-ovens and a coal-washing plant. The incline is double, and is 1400 feet deep, being driven nearly on the dip. The first and second levels have been worked, except for the pillars, while the output of 500 tons per day is being mostly obtained from the third level, and a fourth level is being driven. The average thickness of coal is 6½ feet, with several partings, and the dip is 13° near the surface, decreasing to 7°. Levels are put out east and west from the slope at 250 to 300 feet apart, to a distance of 3000 feet. They are 8 feet wide and 5 feet high. Air-ways are driven below so as to leave a pillar 9 feet wide. The stalls are opened out on the upper side of the level 3 yards wide, and widened to 7 yards, leaving 4-yard pillars. Eighteen inches of inferior coal is left as a roof, as the top measures are faulty. Six-inch props 6 feet apart support the roof. The cost of mining is also dealt with. By the present method about 4000 tons per acre are extracted.

Anthracite Mining.—Mr. H. M. Chance‡ gives an illustrated description of the anthracite industry in Pennsylvania, illustrations being given of the breaking and cleaning plant, the underground workings, and the surface works. The old method of working by parallel breasts separated by regular pillars of coal is still almost universally used, and a moderate estimate places the quantity lost at 40 per cent.

* *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 187–192, with plate.
† *Engineering and Mining Journal*, vol. liv. pp. 537–538.
‡ *The Engineering Magazine*, New York, vol. iv. pp. 544–560.

Outbursts of Soft Coal and Gas.—Mr. J. Dickinson * describes the extraordinary outbursts of coal and gas that have taken place in the Royley mine of the Broad Oak Colliery at Ashton-under-Lyne. The débris in this seam is exceedingly liable to spontaneous combustion, and as it is necessary to use it for packing, constant care has to be taken, and the heated parts dug out. The section of the seam averages: inferior coal and dirt, 6 inches; impure soft coal with sulphur combination, 18 inches; hard coal, 20 to 24 inches. The strata dip west at 2 in 3 to about 500 yards from the shaft, which is 296 yards deep, and then the seam becomes flatter. The soft coal is used for holing in and then for packing, as it is not of much value. It gives off much gas in new workings, and the methods for rise-working to obviate this danger are given. When the dip-workings had reached a depth of about 500 yards, the outbursts of soft coal began, and occurred apparently under all conditions of working. Generally some warning was given, and then the soft coal came out as dust mixed with gas. Details of the twenty-two outbursts are given, some of which occurrences ended fatally. After consideration, it was determined to keep bore-holes in advance; but, if anything, these were rather detrimental than otherwise, as they admitted air to the coal and apparently caused heating. Driving out slowly was tried with indefinite results; and the value of the prohibition against holing under more than two feet was problematical. Analysis of the coal shows the presence of much sulphur, which rapidly absorbs oxygen from the air. As the outbursts did not commence till the workings attained a depth of 500 yards, the depth was a factor in their cause, but not the only one. Other factors apparently were the pressure of firedamp, and of other gas generated by spontaneous combustion, and the expansion by heat.

Draining Dip-Workings.—Mr. H. F. Bulman † describes some of the methods for draining dip-workings. In some cases this is done by boring holes down to the goaf in old workings below. On a haulage plane, the readiest way is to wind the water by water-tubs or tanks. At Killingworth Colliery, Northumberland, six tubs in a train were run down into the water, being loaded so as not to float, and were partly filled by inlet valves and partly by men with scoops. Siphons are often used with advantage. The greatest lift known to the author is 26 feet on a siphon 600 yards long and 6 inches in diameter. Hydraulic pumps

* *Transactions of the Manchester Geological Society*, vol. xxii. pp. 239–265.
† *Journal of the British Society of Mining Students*, vol. xv. pp. 46–57.

are another means that have been successfully applied. Oil-engines have lately been coming into somewhat extensive use, and full particulars are given of one of these engines which is at work at Burnopfield Colliery. A five-horse-power engine drives a treble-ram pump with 6-inch rams and 9-inch stroke. The delivery pipes are 6 inches in diameter and 1300 yards long. The total lift is about equivalent to a head of 52 feet, and at 30 revolutions the pump delivers 117 gallons per minute. Particulars are then given of the electric pumping plant at the Andrews House Colliery, Durham. The efficiency has been calculated at 47 per cent. as follows :—

Brake horse-power of driving engine at 75 revolutions . .	15·50
The dynamo gives 85 per cent. of this	13·17
The cables give 69 per cent.	9·08
The motors give 80 per cent.	7·27

A novel system of draining a colliery in the Reynoldsville district, Pennsylvania, is described by Mr. F. M. Brown.* The seam worked is the Lower Freeport, and is $5\frac{1}{2}$ feet in thickness. At a distance of about two miles from the outcrop the surface of the ground has fallen 102 feet and the coal is 218 feet below the horizontal, or 116 feet below the surface. A shaft, 12 by 16 feet, was sunk at this point to cut the seam, and a heading then driven on the rise from the shaft to meet a corresponding heading driven from the outcrop. During sinking and driving, pumps of 800 gallons per minute capacity were installed at the shaft. When the headings met, which they did at 5200 and 3900 feet from the shaft and the surface respectively, all rails, pumps, and other valuable material were removed, and the shaft was allowed to fill with water until it overflowed. In this state of affairs, the lower 4500 feet of the drift is also filled with water, while the upper 4600 feet are drained and an area of 25 acres of coal is kept clear of water without the expense of pumping. When the coal in this district is exhausted, the coal below water-level will be drained by pumps.

The system of drainage in the wet long-wall mines at Bruceville, Illinois, is described by Mr. R. Ramsay.† The shaft is 114 feet to the top of the coal, which is 3 feet 2 inches thick, overlain with 10 to 12 feet of soapstone and then by 40 feet of very wet porous sandstone. The shaft pillar is 200 by 400 feet. A sump is made adjoining the shaft, 6 feet wide, 12 feet long, and 6 feet deep, and divided by a partition so that one part can be cleaned at a time. There is no sump

* *Engineering and Mining Journal*, vol. lv. pp. 366–367.

† *Journal of the Illinois Mining Engineers*, vol. i. pp. 100–105, with five plates.

below the cage. The steam-pump has a 20-inch steam end, 14-inch water end, and 24-inch stroke; a throttle valve in the steam-pipe is controlled by a float on the water in the sump. There are also two smaller steam-pumps which bring the water from the workings to the main sump through 8-inch suction pipes, from which branch off 2-inch pipes into the workings. At the face small sumps are dug 2 feet square and 2 feet deep, and a stopcock and strainer at the ends of the small pipes are laid in it under the water. The stopcock is of brass and is controlled by a float, so that it is closed if the sump is drained, thus preventing the pump from drawing air from any point. No. 2 shaft has as many as 200 of these sumps working at one time up to half a mile from the bottom, and delivering 500 gallons per minute. The roads squeeze so badly that it is impossible to ditch, and hence this plan of drainage has been adopted.

Pumping Appliances.—Mr. W. W. Millington* describes the pumping plant recently erected at the Woodpark Pit, Bardsley. The engine is of the direct acting, compound, condensing, underground type. The cylinders are 15 and 26 inches in diameter, and the differential pump rams are 5 and $7\frac{1}{4}$ inches in diameter, the common stroke being 3 feet. The air pump is double-acting, 8 inches in diameter. Steam at 80 lbs. pressure is supplied by two underground Cornish boilers $5\frac{1}{2}$ feet in diameter by 18 feet long, with flues $2\frac{3}{4}$ feet in diameter. A complete trial was made of these pumps, full details being given. At $23\frac{1}{2}$ strokes per minute, 120 gallons of water was lifted 1341 feet, showing a slip in the pumps of $3\frac{1}{2}$ per cent. The indicated horse-power was 59, and the pump horse-power 50, showing an efficiency of 85 per cent.

A large pumping engine, intended for draining a drowned-out shaft in Poland, has recently been described.† The engine is of the horizontal receiver compound condensing type, and is intended to lift 20 tons of water from a depth of about 540 feet per minute at 10 revolutions. Particulars of the arrangement of the engine are given.

Nagel‡ describes the pumping plant at the collieries of the Mokta-el-Hadid Company at Gagnières, in the Gard coalfield. The plant is underground, and is designed to raise about 13,000 gallons of water hourly from a depth of 325 yards, at not more than 50 revolutions per minute.

* Paper read before the National Association of Colliery Managers, February 28, 1893, through the *Colliery Manager*, vol. ix. pp. 62–63.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 427.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. v. pp. 631–646.

The engine-room is close to the shaft, and is 48 feet long by 16⅓ feet wide, and 15 feet high to the top of the arched roof. The walls are about 30 inches in thickness, and support H-girders above the engines to facilitate repairs. A large reservoir space is provided for collecting water. There is a compound steam-engine which has tandem cylinders 19 and 31½ inches in diameter, with a 29½ inch stroke. There are two fly-wheels. The pumps are two single-acting, with cylinders 5·8 inches in diameter and 29½ inch stroke.

Mr. R. T. Moore * again describes his hydraulic system of pumping, in which the power is transmitted from the engine to the pump by a water column instead of rods. The application of the method to sinking is mentioned. As far as the efficiency is concerned, 68 per cent. was obtained in one case where there was an inclined distance of 800 yards between the engine and the pump. It was pointed out in the discussion that over 80 per cent. efficiency is obtained in pumps driven through rods, but the convenience and easy application of the hydraulic system enable it to be used in-bye, and the most economical form of rotary engine can be employed, instead of a slow-moving beam-engine.

The question of pump valves is discussed by Mr. D. Baird, † who describes the various forms in use. These are considered under three groups, single and double bent flap valves, single bent and double bent disc valves. The application of the several forms under different conditions is considered.

Mr. W. J. May ‡ points out that there is often a considerable amount of power lost at mines by letting the water run away from the pumps without utilising its head in the water-race. In some instances it is possible to use it to drive a water-wheel.

Electric Pumping Plants.—In the course of some discussion § on the electric transmission of power, Mr. C. C. Leach gave particulars of two sets of tests made with an electric pumping plant at the Seghill Colliery, with some account of the plant itself. The current is taken through 3160 yards of $\frac{7}{16}$ copper cable. The motor is 11 horse-power of the Goolden gas-tight pattern, and drives a three-plunger, single-acting pump with helical gearing at 24·87 to 1. The vertical lift is 121·88 feet, and length of pipes 917 feet, two 4-inch pipes being used

* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 331–342.

† *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 130–139, with five plates.

‡ *Colliery Guardian*, vol. lxiv. p. 1073.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 127–143.

on the delivery side. The following amongst other details are given as the average of two sets of tests :—

Indicated horse-power of engine	10·65	12·40
Water pumped per minute, measured gallons . .	80·38	90·08
Power in water pumped, including friction in pipes, horse-power	3·39	4·00
Useful effect	31·88	32·25
Loss in engine and dynamo	27·73	30·00
Slip in pump, per cent.	17·27	17·90

The question of gearing arose, and a suggestion as to the use of centrifugal pumps was made in the course of this discussion. Mr. H. Palmer summarises the power lost and used as follows :—

Engine.	Generator.	Cables.	Motors.	Pumps.	Pipe-friction.	Water lifted.	Total.
22·33	6·73	13·09	6·25	9·93	25·30	16·37	100·00

Pipe-friction and water lifted together give 41·67 per cent., the efficiency of the plant.

Illustrations are given * of the electrically-driven pump at a colliery at Duryea, Pennsylvania. The pump is a three-throw one, with 6½-inch plungers and 8-inch stroke, mounted together with the motor on a truck. It runs at 42 revolutions per minute, and is driven by a 7½ horse-power motor. The generator is of 10 horse-power, and supplies current through 1700 feet of copper wire.

Mr. D. Hunt † describes a small electric pumping plant erected at Bent Colliery, Hamilton. The pump is used for supplying water to the engines, &c., from a distance of about 500 yards. An electric lighting circuit is also run off the dynamo.

Mr. T. P. Hewitt ‡ describes some of the difficulties from sparking at the commutators in the motor used for driving a pump. Brass gauze brushes were successfully used to overcome this difficulty. The motor is cased in. The loss of power is small, and is economical at distances exceeding 100 yards.

Ventilating Appliances.—Some observations on fans of different types working on the same upcast shaft are given by the Rev. G. M. Capell, § and a number of tests of various fans working under these

* *Engineering and Mining Journal*, vol. lv. p. 53.

† *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 193–198.

‡ *Transactions of the National Association of Colliery Managers; The Colliery Manager*, vol. ix. p. 7.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 203–218.

conditions are quoted from several authorities to show that the Capell fan gives the greater efficiency. Amongst other things, two points are brought out: first, that fans passing different volumes of air from the same mine may show different water-gauge; and, second, that different makes of fan affect the gauge at varying distances in diverse manners, throwing back the gauge to a greater or less distance. This paper was keenly discussed, considerable doubt being thrown on the value of the experiments adduced and on the points above mentioned.

Some illustrations and description of experiments with Bumsted and Chandler's fan and engines have been given.* At the Cossall Colliery, near Nottingham, one of these fans is driven by a pair of compound single-acting engines, one on each side of the fan. The diameters of the low and high pressure engines are 24 and 16 inches respectively, with a stroke of 16 inches. The cylinders are placed tandem, and have piston valves. The cranks run in an oil bath. At 220 revolutions with 125 lbs. boiler pressure and cut off at half stroke in the high-pressure cylinder, the engines indicate 320 horse-power. The fan is 15 feet in diameter and 6½ feet wide. A number of tests are given, of which the following are selections:—

Revolutions.	Water Gauge in Fan Drift.	Volume of Air.	Horse-power in Air.	Indicated Horse-power of Engines.	Efficiency.
150	2·8	171,904	75·9	106·48	71·28
151	3·1	173,000	84·5	117·17	72·1
204	5·2	208,102	170·6	260·25	65·5
205	4·75	246,078	184·3	261·40	70·5
204	5·5	214,934	186·4	263·50	70·74
200	4·5	232,696	165·1	230·00	71·5

In some of these experiments external air was admitted at the top of the upcast, as it was impossible to pass the guaranteed 250,000 cubic feet per minute for the fan through the mine at the stipulated water gauge. When the fan drift was entirely closed the water gauge was as follows:—

Revolutions . .	150	155	180	140	160	164	186
Blade, top speed	7068	7304	8482	6597	7539	7728	8764
Water gauge .	4·1	4·4	6·0	3·5	4·6	5·0	6·4

Some results of further tests and other particulars of these fans have also been given by Mr. N. Chandler.†

* *The Engineer*, vol. lxxv. p. 61.

† *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 161–171.

Mr. J. Allardice* describes an arrangement for reversing the air current, and the advantages of being able to do so. The plan is shown in connection with a Guibal fan and also with a Waddle fan, a casing being required in the latter case. It consists in so arranging the air-drifts with doors that the fan can exhaust from the pit or drive air into it according to the position of the doors.

A. Macquet† describes some tests of a Rateau fan, the first of its kind erected in Belgium. It is 9 feet 2 inches in diameter, the inlet is 5½ feet in diameter, and is flared out to 7 feet in diameter where it joins a large chamber connected to the air drift. It is driven by an engine with a four-foot stroke and a piston diameter of 2½ feet. Measurements were taken of the fan and engine speeds, the amount of air passed by the fan and the water gauges, the indicated horse-power, and the temperature and pressure of the air. Each test lasted three minutes. The tests were not made in the mine itself, but in some shafts and galleries in which artificial resistances were introduced. The results of the tests are fully set out in the form of curves, and are also given in tabular form. Amongst these results are the following :—

Description.	Revolutions per Minute.	Volume.	Water Gauge.	Efficiency.
		Cubic Feet.	Inches.	Per Cent.
For maximum speed . .	293	1670	8·56	61·2
For maximum water gauge .	228	1919	8·78	64·1
For maximum volume . .	265	2664	6·69	...

Mr. R. W. Berkley‡ describes a gauge for measuring small differences of air pressure. It consists of a U-tube $\frac{1}{10}$-inch in diameter, with the upper ends of larger diameter. A bubble of air is introduced into the smaller tube in the liquid column to act as an index.

Some of the applications of the water-gauge are described by Mr. W. Rutledge,§ the effect of a fall in an air-way, or other alterations in the air-current being mentioned.

Safety-Lamps. — The Piston safety-lamp‖ is one of the most

* *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 80–83, with plate.
† *Revue Universelle des Mines*, vol. xx. pp. 304–326, with four plates.
‡ *Journal of the British Society of Mining Students*, vol. xv. pp. 84–85.
§ *Journal of the Illinois Mining Institute*, vol. i. pp. 17–25.
‖ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 179–181, 187–192, with illustration.

recently-devised forms. It consists of five principal parts, a strong case into which the other parts are pushed upwards, an outer gauze and shield, an inner tube and separator, a glass with brass end rings. The oil reservoir is placed below these parts, which are kept in place by a bottom plate and lead rivet. A spring cushion is provided under the bottom plate to save the lamp from shock when set down. The wire-gauze is placed outside the shield. The objects and advantages of this lamp are described by Mr. W. E. Teale.*

Mr. J. T. Bennett † describes the origin of the safety-lamp and several of the more recent forms. Attention is also drawn to the Piston safety-lamp.

Mr. A. Dick ‡ states that the Davy lamp is still the favourite lamp in the United States for testing for gas. The Ashworth Hepplewhite Gray combination is mentioned as a good combined testing and illuminating lamp. A similar form, called the Nelson lamp, has been made in Pennsylvania. The Richards lamp, another gas-testing lamp, is a modified Clanny.

H. Kämmerer § and T. Oppler have tested a number of different types of safety-lamps. Mixtures were made of different volumes of air with the vapours of a number of the more volatile combustible organic compounds, such as ether, alcohol, and benzene, as well as carbon bisulphide and hydrogen. One of the lamps examined could in no way claim the name of a safety-lamp, but, this one excepted, all the other lamps gave results with all the mixtures of vapours examined, except those of carbon bisulphide with air, which are embodied under the following heads :—(1.) If only a few per cent. of the gas is present, the flame is slightly lengthened, and it was observed in this connection that the flame of benzene lamps is far more sensitive than that of oil lamps. (2.) If larger quantities of gas are present, the elongation of the flame becomes still more marked; it becomes unsteady and rises above the wire-gauze to the cover of the wire cage; the flame, when it has been lengthened to this extent, shows a curved shape, is of a reddish hue in its upper portion, and begins to smoke. (3.) If the respective volumes of air and gas are such that the oxygen present only just suffices for the complete combustion of the gas—when, that is, the explosive power of

* *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 172-176, with plate; *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 115-118, with plate.

† *Proceedings of the National Association of Colliery Managers*, vol. iv. pp. 356-362.

‡ *The Colliery Engineer, Scranton*, vol. xiii. p. 161.

§ *Journal für Gasbeleuchtung*, vol. xxxvi. p. 101.

the mixture has reached its maximum—the flame lengthens rapidly, the gas mixture takes fire within the gauze, forming a cap around the flame; the true flame of the lamp then becomes extinguished, the cap continuing to burn along the face of the gauze for some time. (4.) If more oxygen is present, then the same cap formation is observed, but it is much sooner extinguished, although it was found that it lasted longer in the oil-fed lamps than in those in which benzene was the illuminant employed; this is probably due to the gauze having become more heated in the case of the oil lamps.

Mixtures of gas containing carbon bisulphide did not follow these rules, except in those cases in which the quantity of the carbon bisulphide vapour in the air was so small as not to increase to any great extent the length of flame of the lamp. If, however, this becomes lengthened to an extent sufficient for it to reach the top of the lamp, or if a cap was formed, the carbon bisulphide vapour outside the lamp was very soon brought into flame, even in the case of those lamps which were perfectly safe for every other gas mixture that was tried in the course of the author's experiments.

In the course of some remarks on safety-lamps for lighting and gas-testing purposes, Professor F. Clowes* gave the illuminating power of a Marsaut lamp, as compared with a candle as unity, as 0·53 in still air, 0·83 in an air current of 180 feet per second, and 0·68 in one of 300 feet per second.

Mr. J. P. Rees† describes a lock for safety-lamps which prevents the lamp from being opened unless the lamp is turned upside down and the light therefore extinguished. It consists of a small tube soldered vertically on the upper part of the lamp, and a corresponding socket on the lower part. A bolt in the upper tube drops down when the lower part is screwed home, and is of such a length that it lies partly in the socket and partly in the tube.

Mr. Prestwich‡ has exhibited an electrical device applicable for relighting safety-lamps of any type. It consists of a platinum wire attached to terminals, which can be brought into connection, by exterior contacts under the bottom of the lamp, with the terminals of a battery or accumulator. The lamp can thus be relighted, or can be lighted at the pit bottom after locking, by the use of accumulators charged at the surface and sent below ground.

* *Colliery Manager*, vol. ix. pp. 66–67.
† *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 169–171.
‡ *Transactions of the Manchester Geological Society*, vol. xxii. pp. 150–151.

Mr. H. White* describes the Coal-miners' electric lamp. A single-fluid primary battery is used with non-corrodible platinum connections. The plates are of zinc. A three-cell lamp weighs 4 lbs. 2 oz., and a four-cell lamp weighs 5 lbs. 6 oz. The consumption of zinc in these two lamps is given as ¾ and 1 oz. respectively for ten hours. The incandescent lamp is mounted with a glass shield, breakage of which puts out the light.

Mr. J. P. Rees† describes the Miners' electric lamp. The lamp bulb is protected by an outer glass casing, and air under pressure is forced between the two glasses. The pressure of this air causes the completion of the circuit, so that if the outer glass be broken the lamp is extinguished. It burns for 10 hours, gives a good light, weighs 5½ lbs., costs 25s. originally, and a shilling per week for maintenance. The current is supplied by a primary battery.

Some particulars are given of the Bristol electric lamp by Mr. T. Raaschow.‡ This is an accumulator lamp with three cells, and is said to be the lightest electric lamp made, a lamp giving 1½ candle-power for seven hours, weighing 27 oz. Estimates for the cost of installation and maintenance of these lamps are given.

The Detection of Firedamp.—In discussing the detection and estimation of small proportions of firedamp, petroleum vapour, and other inflammable gas or vapour in the air, Professor F. Clowes§ gives the criterion of an apparatus as to its convenience, its capability as an illuminator, its safety, and its accuracy and range. The first three have been fairly worked out, but the latter seemed to be worthy of further investigation. Most of the apparatus that have been devised for measuring firedamp depend on three different principles—on the increase of brightness of a heated platinum wire, on the decrease of pressure caused by burning the gas, or on the production of a cap over a flame. Liveing's apparatus is an example of the first type, and some experiments made by Mr. J. Grundy in the author's test chamber are given to show its accuracy. Hydrogen flames have been proposed, and also alcohol flames, to replace the ordinary safety-lamp, and the author has devised a means of combining the hydrogen burner with a safety-lamp. A large number of

* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 151-153, with plate.

† *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 167-168.

‡ *Ibid.*, pp. 36-47.

§ *Journal of the Society of Arts*, vol. xli. pp. 307-323; Patent No. 6051 of 1892; *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 441-459; *Journal of the Society of Chemical Industry*, vol. xii. pp. 326-327.

tables and diagrams are given to show the height of the cap in different percentages of gas with the ordinary oil flame, the alcohol, and the hydrogen burners. The delicacy of the indications obtained by these means and by Liveing's apparatus is also shown with the aid of curves. The conclusions drawn from these experiments, and the advantages gained by the use of the hydrogen flame, are set forth to show that the latter gives uniform and constant indications, and that it is readily adjustable. It was found also that an ordinarily dusty air, such as that found in mines, does not affect the indications.

In the most recent form of the author's lamp, a small cylinder, measuring about 5 inches long and 1 inch in diameter, weighing about 1 lb., is charged with hydrogen at 100 atmospheres pressure, and will supply the standard size of flame for forty minutes. This small reservoir is readily attached to the lamp, and is charged before use from a larger reservoir.

Firedamp in the Anzin Collieries.—An interesting history of firedamp in the collieries at Anzin, from the year 1810 up to the present time, is given by A. François.* The state of the mines at that date is described, and an account is given of the various explosions, commencing with the first in 1811. The various means that were proposed to overcome the difficulties incidental to the evolution of firedamp are referred to at length, including the introduction of the safety-lamp and of improved means for ventilation. The regulations that were promulgated from time to time are also set forth.

The author traces the history of mechanical ventilation at the Anzin collieries since 1852 when the first fan was installed. From 1852 to 1874 the output increased from 720,000 tons to 2,000,000, and the number of workmen from 5800 to 12,000. During this period there were 17 accidents causing 71 deaths. During the period from 1874 to 1883 throughout the collieries was applied the principle of the prevention of firedamp explosions by the employment of powerful fans and of well-kept and wide roads. In the period from 1884 to 1892 the introduction of the Marsaut lamp took place, the Ser fan was employed, the last furnaces disappeared, and safety explosives came into use. The conclusion drawn by the author from his researches is that energetic ventilation not only assures the health and safety of the miners, but also renders it possible for the working costs to be reduced. During the five periods from 1811 to 1892 the number of victims per million tons raised was successively 19·32, 1·79, 3·94, 1·45, and 0·13.

* *Annales des Mines*, 9th Series, vol. ii. pp. 233–284.

Electricity in its Relation to Mining.—The possibility * of conveying power over long distances was well shown at the Frankfurt Exhibition, where a yield of 73·5 per cent. was obtained of the power generated by turbines at Lauffen on the Neckar, 105 miles away. The current was a converted alternating one. Satisfactory as were these results, it must not be forgotten that the cost of the plant was so large that profit could only arise if the price of coal at the point where the current was to be used was exceptionally high. So, too, it has not been considered financially possible to convey the power to be generated by the works in course of completion at Niagara for any great distance. The alternating current has not as yet been much used in mines, mainly due to the short distances the current has to be taken, and to the great safety which is experienced in the use of machines of this type. At the Zauckerode Collieries, where the first electric mine railway was employed, there has been in use for the past two years an electric-driven chain line, with a daily capacity of 500 waggons. The electric railway, which was laid down in 1882 at the Oppel shaft at Zauckerode, is still in active use. It has a length of about 800 yards. The daily capacity of this line is 800 waggons of 992 lbs. each, the annual cost being 2¼d. per ton-mile. An annual profit of £150 is made by this line as compared with horse labour to do the same work. The use of electricity for pumping and hoisting purposes is also referred to.

Mr. D. L. Lloyd † compares electric with compressed air transmission of power, greatly to the disadvantage of the former when used for driving coal-cutting machinery. The comparisons are chiefly made by calculating the sizes of the various cylinders in the engine and motors, and by using ammeters and voltmeters for the electric plant. The efficiency is thus given as 19 per cent. for the electric plant, and over 60 per cent. for compressed air.

In the course of discussion ‡ on various papers on the electric transmission of power, further reference was made to the use of safety conductors in mines, and to gas-tight covers for switches. Mr. S. F. Walker described some forms of safety cut-outs, which were preferable to fusible plugs.

Some good illustrations of the collieries of Hill's Plymouth Company, Merthyr Tydvil, have recently been published,§ and an account is given

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 91–96.
† *Journal of the Illinois Mining Institute*, vol. i. pp. 187–193.
‡ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 127–143.
§ *Engineering*, vol. lv. pp. 633–640.

of the early history of the workings, and of Trevithick's engine used there. A description is also given of the electric haulage and lighting at the Abercanaid pit. The conductors are made of well-insulated armoured cables, in lengths of 150 yards, each weighing 30 cwt. Each length is furnished with copper end pieces, which are bolted together to make the joint, and are protected by insulation in cast-iron boxes.

The construction of electric light switches for use in mines is discussed by Mr. S. F. Walker.* The essential features are a quick make and break and large contact surfaces, with a substantial construction to allow for rough usage. In his own switches, the 100 ampère switches have two pairs of surface contacts of 4 square inches each.

Signalling in Mines.—Mr. F. S. Marsh † describes the manner in which he has used the telephone in conjunction with the usual electric signal-wires. On receipt of a special signal, the engine-driver takes down his telephone, which operation, by means of an automatic switch, cuts out the batteries. Below ground a portable transmitter is used, and can be hooked on to the wires at any point.

The use of telephone apparatus in mines is discussed at some length by Mr. S. F. Walker,‡ the various forms of transmitters, receivers, and connections being described. A plan for speaking and signalling in the mine without wires is also suggested for further experiment. In this system, two well-earthed plates at the surface are supplied with current from a source of low electro-motive force. It might then be possible to pick up some of the earth-current in the mine by plates earthed in suitable position, and to utilise them for the telephones.

Mr. S. F. Walker § discusses the working of electric signals from the electric light service in mines. Several plans have been adopted, the usual one being to put the bell in the circuit between the two cables with a resistance. As a resistance an electric lamp is advantageously employed. In some cases one terminal of the bell is earthed by connecting it with the rails, but this is not to be recommended, as it strains the insulation of the cables and dynamo, and of the coils in the bell itself, besides which it is a likely source of danger from shocks or sparking.

Mr. M. Mercier ‖ describes a form of electric bell and push, designed

* *Colliery Guardian*, vol. lxv. p. 438.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 1007-1009, with plate.

‡ *Colliery Guardian*, vol. lxiv. p. 1119, and vol. lxv. pp. 67 and 208.

§ *Ibid.*, vol. lxv. p. 579.

‖ Paper read before the National Association of Colliery Managers, February 28, 1893; *Colliery Manager*, vol. ix. p. 62.

so that it is gas and damp proof. Any risk of sparking is thus obviated.

The Prevention of Accidents in Mines.—C. de Sinner* deals at some length with the causes and prevention of accidents in mines. The statistical side of the question is also discussed. With regard to explosives for bringing down coal the author mentions the precautions that should be observed in charging and tamping the holes in priming and firing the shots, and in the case of the explosive itself. Boilers and steam-pipes when used underground should be placed away from the coal, whilst careful and periodical inspection of all the machinery is most necessary. The various methods used for transmission of power are briefly reviewed, and then the transport on levels and inclines, together with the winding appliances, are investigated, especial reference being had to the exhibits and reports at the Berlin and Paris exhibitions. A number of illustrations are given to show various forms of stops and fences for use on inclines. Means of ascent and descent are also dealt with.

The Hill Farm-Parrish Mine Fire.—Mr. F. A. Hill† describes the Hill Farm-Parrish Mine fire, with the means used to extinguish it. This colliery is in the Connellsville coke region, near Dunbar. The coal dips 8° south-west, and is opened by two slopes. To avoid carrying steam pipes down the incline an 8-inch borehole had been put down, and when connection was made with the workings a small feeder of gas was accidentally ignited. This set fire to some brattice cloth, and then to some waggons, and the fire spread rapidly. After some exploratory work, the Hill Farm slope was sealed and the workings cut off from the Parrish slope. When the mine had been closed for fifty-eight days an attempt was made to reopen this incline, and after some experiments, it was decided to cut through the manway into small sections, and to clean up everything on the way down. Air was led down the manway, and a line of pipe laid down to take water for quenching the burning material before hoisting it. With some considerable difficulty the work was carried through to completion, and the colliery is now at work again. It was found, as it has been in other places, that there was no serious fire in the coal itself, but in the broken slate in the roof and ribs the fire

* *Bulletin de la Société Vaudoise des Ingénieurs et des Architectes*, vol. xvii. pp. 261-724; and vol. xviii. pp. 15–25, 46–48.

† *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

extended for several feet. This had to be blasted out by boring a hole, cooling it with water, and hurriedly inserting and firing a dynamite cartridge. The fallen mass was then extinguished and removed.

IX.—*COAL-WASHING.*

Screening and Picking Coal.—Mr. A. S. Douglas* describes a form of rotary screen and picking table for coal. Two or more grated rotary tables are mounted on the same vertical shaft. The lower table is horizontal and the upper ones slope to the outer edge. The tables increase in diameter downwards. Coal is fed from a tippler through a shoot to the centre of the upper table, and the various sizes are separated by the screen bars in the successive tables. Rakes spread the coal evenly, and clearer bars guide the picked coals into the shoots. When the rakes are raised a catch is automatically thrown into gear with the tippler to prevent a further supply. This being done, if the coal is so dirty that the table has to revolve two or three times to allow of complete separation, a loaded gate in the hopper allows it to clear itself if overloaded. A screw under the footstep bearing of the shaft is arranged to allow it to be raised for inspection.

Mr. W. Hay† describes the screening and picking belts erected at the Stanton Colliery, near Burton-on-Trent. The tubs are elevated 15 feet from the weighing machine, and the coal tipped on to a jigging screen 6 feet long by 5 feet wide, with a fall of 8 inches per yard. From this the coal is taken by a creeper chain, moving at 35 feet per minute and sloping slightly to a large jigging screen 13 feet long. This carries two sets of bars each 5 feet wide and 6 and 5 feet long respectively. Both are pitched 6 inches per yard, and the spaces between the bars are $2\frac{1}{2}$ and 4 inches between the two sets. The speed is 80 to 90 strokes per minute. The nuts from the top screen are taken by a 2-foot belt, travelling at 40 feet per minute, and on this they are picked by boys before they reach the loading shoot. The coal passing through the lower screen passes over fixed screen bars 3 feet long to a movable pan worked from the jig. Al. the large coal goes on to a $3\frac{1}{2}$-foot picking belt. This belt is inclined and spans three lines of rails. It runs at 25 feet per minute, and takes the

* *Transactions of the National Association of Colliery Managers*, Dec. 10; *the Colliery Manager*, vol. ix. pp. 5–6, with illustrations.

† *Ibid.*, Dec. 17; *Colliery Manager*, vol. ix. pp. 6–7.

large coal to another belt 105 feet long and 2 feet wide, which runs parallel with the line on which the trucks to be loaded with large coal are situated, at a rate of 37 feet per minute. This belt is only about 3 inches from the top of the trucks in which the men are stationed to select the coal they require. Near the end of the belt fixed guide pushers are provided to direct the coal to the side.

A screening plant intended for a colliery in Aberdare has recently been described.* It consists of a fixed screen 12 feet long, a shaking screen 5 feet long, and belts 56 feet long and 5½ feet in width.

The cleaning plants at the collieries in Illinois are described by Mr. T. R. Stockett.† At the Gillespie mine there is an inclined shaking screen 14 feet long, the lower 12 feet being perforated with 1¼-inch round holes ¾ inch apart. From the screen the coal is delivered on to a picking belt, and thence over a fixed screen to the railway trucks. The slack and small coal is taken by elevators to a roller screen, where it is cleaned and sized. The belt consists of wooden slats fixed to sprocket chains, and a self-regulating door is used in the hopper. This was the first plant erected in the State, and there are now several others in operation. When the coal was harder than at this mine, a combined oscillating screen and picking table is in use. These screens are made of any length, and have their lower portion covered with plates where the coal is picked over, and they discharge the coal direct into the trucks. In one plant there are three of these screens side by side. The coal which falls through the upper part of these screens in each case is received by a second and a third screen placed underneath, so that four sizes are made. In another plant, the shaking screen and table are 20 feet long, and arranged to make two or three sizes of coal as desired, by placing plates over part of the second screening surface. Plates perforated with round holes are preferred by the author to bar or wire mesh screens, as they have a smoother surface and require less inclination.

Mr. R. Mauchline‡ describes the coal-cleaning plant of the Mary Lee Coal Company at Lenisberg, near Birmingham, Alabama. The coal as it comes from the inclined shaft is tipped on to vibrating screen bars 1½ inch apart. About a third is thus separated as lump coal, and the remainder is taken to a revolving screen over the Robinson washer. This screen is 5 feet long and 2½ feet in diameter, with a ⅝-inch mesh. The nut coal is passed through rolls ¾ inch apart, and then taken back

* *Colliery Guardian*, vol. lxv. p. 814.
† *Journal of the Illinois Mining Institute*, vol. i. pp. 26–41, with six plates.
‡ *Engineering and Mining Journal*, vol. liv. pp. 527–528.

to the washer. The washed coal is coked in the ovens, of which there are 110, and the yield of coke is given at about 60 per cent.

Mr. E. Low * describes, with the aid of illustrations, the coal-loading screens at Dunlow, Virginia. The tubs from the mine are brought by a tram-line to a floor 60 feet above the railway siding, where they are discharged into bins, and the coal is screened by three superimposed screens. Dimensioned sketches of the woodwork and of other parts are given.

Coal-Washing Plant at Brookwood, Alabama.—A description of the coal-washing plant at Brookwood, Alabama, is given by Mr. R. Boericke.† The coal is tipped from a wooden trestle on to a double-table shaking screen, which makes three sizes. The larger sizes are picked on two belts, 73 and 68 feet long respectively, and the largest size is then re-screened. The lump coal is lowered by an endless chain into the trucks. The small coal is crushed and sized in a double revolving drum, and is sent to eleven double-compartment jigs, each capable of handling 5 to 7 tons hourly. The reduction of ash varies from 46·9 to 77·5 per cent.

The Lührig Process of Washing and Treating Coal.—The Lührig process of washing and treating coal is discussed by Mr. J. P'Anson,‡ who states that a complete plant for treating 1000 tons a day will shortly be at work at the New Randolf Pit of the North Bitchburn Coal Company. Reference is made to papers by previous authors on the subject of coal-washing, and also to the economy and desirability of using cleaned coal. At the Denaby Main Colliery, the coal lost in the dirt is stated not to exceed one-half per cent. in daily practice. The first principles on which coal-washing depends are considered, and a description is given of the Lührig plant at Motherwell, where 1500 tons is treated daily.§

The Campbell Coal-Washer.—The results of work with the Campbell coal-washer are given by Mr. W. B. Phillips,‖ together with a description of the machine by Mr. F. Cawley. The machine is a form of bumping-table. The width of the table is 30 inches and its length 8 to 10 feet, and it has a perforated false bottom about $\frac{1}{4}$ inch

* *Engineering News*, vol. xxviii. pp. 414–415.
† *Engineering and Mining Journal*, vol. lv. p. 270, with illustrations.
‡ Paper read before the Cleveland Institution of Engineers, February 20, 1893.
§ *Journal of the Iron and Steel Institute*, 1891, No. I., p. 348; 1892, No. I., p. 390.
‖ *Engineering and Mining Journal*, vol. lv. pp. 128–129.

above the true bottom. In the later machines the bottom is made of oak strips 30 inches long by 4½ inches in width. A specially formed curve is given to both bottoms. The table is supported from above by hangers, and has an endways movement of 3 to 6 inches, being retracted by cams and levers, and allowed to fall back against a bumping-block. Water is supplied between the bottoms and by sprays. Coal is discharged continuously at the tail end and dirt at the head end. The author finds that each table will wash 40 to 45 tons of coal daily, with the expenditure of ½ horse-power and 300 gallons of water per ton, at a cost of 1 to 1·5 penny per ton. Most of the coal washed was slack which would pass a ¾-inch screen. The dirt in the unwashed coal averaged 12·71 per cent., and in the washed coal 2·73 per cent. The coal passing over the head with the dirt was 1·64 per cent. The sulphur was reduced from 4·20 to 3·18, and the ash from 10·73 to 8·56 per cent. The coals washed were Nos. 9 and 11 of the Kentucky series.

Washing Coal in Tennessee.—Mr. G. W. Whyte* gives an account of some experiments on the washing of coal from the Nelson Mine, Tennessee. This coal averages 14 per cent. of ash, but by curtailing the output of the mine by 24 per cent. the ash could be reduced to 9·45 per cent., or 15·75 per cent. in the coke. Fifty tons of the run of the mine was treated. The coal was screened, the larger lumps over 1½ inch hand-picked on belts and crushed, and then the whole was screened into four sizes. The three larger sizes were washed on bashes at 72 strokes per minute, then re-crushed, and treated like the smaller size on bashes running at 140 strokes. The results are given, and show that with this coal there was a loss of 27·30 per cent. of coal, and a coke with about 14 per cent. of ash was produced.

Loading Coal.—Mr. M. Walton Brown† describes the coal-loading wharf at Barsée, in connection with the Bethune Collieries, Pas de Calais. There are two tipplers, each capable of dealing with a waggon holding ten tons. They work by gravity, but are controlled by a brake and a hydraulic regulator. The coal is received by a wide shoot, which leads it to an articulated pipe by which it can be directed into the hold. A chain-hauling gear is used to move the boats. At the Lens Collieries the waggons are tipped sideways by the aid of a small crane attached to a locomotive.

* *Engineering and Mining Journal*, vol. lv. p. 80.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 1019-1021, with plate, p. 1026.

The arrangements used by various French collieries for loading coal into boats, and shown at the 1889 Exhibition, are described by A. Habets * in some detail with the aid of two plates of illustrations.

Various forms of conveyors for moving coal and coke, designed by Mr. G. Little, especially for use in gasworks, have recently been illustrated.† Some of these consist of plates attached to wire ropes, and are intended to push the coal along troughs. Other forms consist of tray-conveyors, and one of these latter devices is intended to take the hot coke from the retorts and to cool it. For this purpose the conveyor moves in a trough kept filled with water. Tilting bucket conveyors for filling the coal or coke are also illustrated.

The Manufacture of Briquettes.—An illustration is given ‡ of a briquette-making machine which had been at work at Blantyre for some fifteen months. It has been used for making briquettes from coke, breeze, and pitch. The machine is so arranged that the pressing hand, which weighs 7½ cwt., drops into the mould as soon as it is filled, and is then drawn back to allow more material to be fed in. The surplus material is struck off, and the pressing hand again descends. Pressure is then applied three successive times by means of cams, the last application being the heaviest. The feed, pressing, and delivery are automatic, and the parts are easily adjustable and renewable.

* *Revue Universelle des Mines*, vol. xix. pp. 336–343, with two plates.
† *The Engineer*, vol. lxxv. pp. 170–172.
‡ *Iron*, vol. xli. pp. 47–49.

PRODUCTION OF PIG IRON.

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I.—*BLAST-FURNACE PRACTICE.*

Relining a Blast-Furnace.—In relining a blast-furnace at Youngstown, Pennsylvania, Mr. T. G. Davis * abandoned the blowing-out method. That which he employed consisted in shutting off the blast and then drowning out the furnace with water, the stock being afterwards shovelled out. He has also abandoned the "sweep" centre pole used by furnace-builders, using instead cords suspended from the top of the well to the top of the boshes, placed 3 or 4 feet apart, and serving as a sufficient guide for the bricklayers. The scaffold is thus kept free from all obstructions excepting the stock brick, and a larger number of men can be simultaneously employed.

The furnace to be relined went out of blast on September 6, 1892, at 5.30 P.M., and the work of drowning it out was immediately commenced. It had been shovelled out and made ready for the bricklayers on September 13. Further operations were delayed until October 3, but upon that date the bricklayers commenced work at 10.30 A.M., and completed the relining by 9 A.M. on October 8. The furnace was ready to light on October 13, but owing to delays did not actually go into blast until the morning of October 16. The first cast of iron was obtained on the following morning, and during the second day thirty-five tons were made. The average daily out-turn of this furnace is 115 tons. It is furnished with two pipe-stoves.

* *Iron Age*, vol. l. p. 792.

Carbon Bricks in the Blast-Furnace.—T. Jung* states that in a blast-furnace the crucible portion of which had been lined with carbon bricks, it was found that in the course of a few weeks the whole of these bricks at the bottom of the furnace had disappeared. This bottom was originally over 30 inches in thickness, but the pieces that had been built in were small, and the iron appears to have penetrated between these, and lifted the whole of the material. On the other hand, the bricks at the sides had been held in place by the weight of the superincumbent brickwork, and showed no sign of deterioration. A second furnace had been similarly lined with carbon bricks, but these had been built at the bottom in two layers and in large pieces. The upper layer, which was 20 inches in thickness, lasted much longer than did the lining just referred to. Still, in the course of a few months this too had been destroyed, and the lower layer disappeared even more rapidly, having been disintegrated in less than five months. The bricks at the sides held well in this instance also. In view of these results, the author considers that it is necessary that when carbon bricks are used as a lining in this way, great care should be taken to build them in as firmly as possible, and to anchor them well with iron. It is stated that the carbon bricks that are now made possess considerable strength, and that they can therefore be made in sizes of from 27 to 31 inches and more in height, and from 15 to 17 inches and over in width. They undoubtedly form an excellent material with which to line the crucible portion of a blast-furnace, and their use possesses, the author observes, the advantage that it enables the width at the tuyeres to be increased from 8 feet 3 inches or 9 feet 3 inches to as much as 10 feet 6 inches or 11 feet 6 inches. Assuming, too, that this carbon bottom disappeared after a short time, and that in its place a furnace bear had been produced, this in its turn will act as the furnace bottom, and the better the larger it may be, if the spaces between it and the furnace walls are filled in with carbon and brickwork mixed, or with a stamped-in carbonaceous material, the whole being carefully enclosed. As the author points out, the first cost of such a bottom, containing as it would from 150 to 200 tons of iron, would naturally be large. But once produced, the usual cost for repairs would disappear, and if some form of water-cooling was adopted, it would be possible to regulate the height of the bottom at will.

Cooling Blast-Furnaces.—M. P. Duthu† refers to the results

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxvii. p. 279.
† *Bulletin de la Société de l'Industrie Minérale*, vol. vi., No. 2.

which have been obtained with the small charcoal blast-furnaces at Ria, in the Eastern Pyrenees. These furnaces smelt roasted spathic ore, assaying 55 per cent. of iron. The out-turn has been a large one, 0·5 to 0·6 of a ton for each cubic yard furnace capacity. With this large out-turn, however, the lining of the furnace was rapidly eaten away. By providing them with a water-cooled steel mantle, extending up to the boshes, this corrosion was entirely avoided, and the mantle itself has been for over eight years in use without requiring to be repaired. The relatively large out-turn of these small furnaces is doubtless due to their large sectional area at the tuyere level, and to the use of comparatively high-grade and readily reducible ore. The charcoal used is about three-quarters of a ton for each ton of metal made, as compared with about a ton per ton in the case of the still higher grade, but much denser and more difficultly reducible ores that are smelted in the Swedish charcoal furnaces. The author draws a comparison between these Ria furnaces and others in use at Firminy and at Pittsburgh, which, in many respects, is greatly in favour of the Ria furnaces. Full details are given with regard to each of the furnaces between which the comparison is made, the Pittsburgh furnace being a large one, having an internal capacity 2½ times as great as that of the Firminy furnace, which, in turn, is seven times as large as the Ria furnace. The daily production is respectively 330 tons, 70 tons, and 15 tons of pig iron.

The Loss of Heat in Blast-Furnaces.—Professor Wedding* observes that the method in common use for calculating the quantity of coke required for a new blast-furnace or for an altered furnace charge is not altogether accurate; indeed, with poor ores it is apt to give too high a result, and with rich ores a result that is too low. A most important factor in these calculations is the quantity of heat that is radiated by the furnace walls, and the factor is not one that is readily accounted for. This loss varies, according to the few accurate calculations that have been published, between 10 and 31 per cent. of the total heat consumed. In English and American works it is customary, the author states, to place it between 18·5 and 23·4 per cent., and in Germany at 26 per cent. At the blast-furnace of the Gleiwitz Works in Upper Silesia, where the furnace conditions have been most carefully calculated, the loss was found to amount to 31 per cent. In his present paper the author gives complete details as to the method of calculating the heat required in reducing the iron from its ore, in also reducing the manganese,

* *Stahl und Eisen*, vol. xii. pp. 1029–1037.

silicon, and phosphorus, in heating the ore during the slag formation, in heating the reduced iron, in heating the molten blast-furnace products, in evaporating the water contained in the ore, in heating the water used for cooling purposes, and the heat carried away by the waste gases apart from the loss of heat by radiation. The author sums up these various sources of loss of heat as follows :—

	Calories.
Pig iron	208,000
Combined water	25,000
Cooling water	10,000
Total . .	243,000

The heat required is further calculated as follows per 0·1 metric ton of pig iron made :—

Description.	Rich Ores.	Poor Ores.
	Calories.	Calories.
Slag	21,000	733,000
Hygroscopic water . . .	7,600	54,100
Waste gases	12,600	128,000
Add as above .	243,000	243,000
Totals . . .	284,200	1,158,100

The mean of these two totals is 720,000 heat units, whilst the average in actual practice appears to be about 450,000. It would appear from the results observed in actual work that blast-furnace conditions in which less than 250,000 heat units are absorbed do not exist, and that when this number exceeds 500,000, the blast-furnace is not an economical one, at least no furnace as yet examined exceeds this figure. The lowest total appears to exist in the case of the Vordernberg charcoal blast-furnaces, while the ordinary coke blast-furnace appears to be the least economical. The author also considers the question of the blast, and then proceeds to consider that of the production of heat in the blast-furnace. The heat brought into the furnace by a kilogramme of blast is tabulated for temperatures varying between 100° C. and 1000° C., being in the former case 23·77 heat units, and in the latter 256·68, varying between 23 and 26 heat units for each 100° rise of temperature. The heat units yielded by the combustion of 100 kilogrammes of carbon are calculated at 459,000, with blast at 500° C., and at 524,000 with the blast at a temperature of 900° C. In actual practice the quantity appears to range between 273,000 in a charcoal blast-furnace, and 494,000 in a coke-furnace. At the Gleiwitz furnace, to which reference

has already been made, this quantity is 487,000, the blast having a temperature of 550°. In conclusion, the author refers to blast-furnaces smelting rich ores and using firebrick stoves; the heat used was found to be 284,200 heat units, while the production, using 100 kilogrammes of carbon per 100 kilogrammes of iron, was as much as 524,000. Thus the loss by radiation and by conductivity through the brickwork of the furnace exceeded 45 per cent. of the total quantity of heat produced. Even had the fuel used been but as 80 kilogrammes of carbon to 100 of pig iron, and with a temperature of blast of 900° C., the loss would still have amounted to more than 28 per cent. of the total heat. From this it is evident that general statements that have been made as to the loss of heat from blast-furnaces in the United Kingdom and the United States by radiation and conduction are apt to be erroneous. In referring to his calculations, the author points out that the percentage of iron in a pig iron never exceeds 97, while it may fall as low as 85. One part by weight of iron requires for its reduction from ferric oxide 1796 heat units, and from ferrous oxide 1352. Manganese absorbs in its reduction from manganous oxide 2000 heat units, and from Mn_3O_4 2273, silicon from silica 7830, and phosphorus from phosphoric anhydride 5760.

The Use of Coke in Blast-Furnaces.—Mr. J. Wister,* in an address delivered before the Foundrymen's Association of Philadelphia, refers to the gradual replacement of anthracite by coke in the blast-furnaces of the United States. In 1867 he built a blast-furnace at Harrisburg in Pennsylvania, the only fuel at that time available being anthracite from either the Schuylkill or the Wyoming regions. The furnace was intended to make 15 tons a day, but its capacity was gradually increased to as much as 45 or 50, owing to changes in the ores and fuel used, and the necessity for an increased out-turn in view of the rapidly declining market value of the product. In the early days between 1868 and 1873, the fuel consumed amounted to from 1½ ton to 2 tons per ton of pig iron made. Now very few furnaces consume more than 1¼ ton of fuel per ton of metal, while the best practice shows a consumption of as little as 1900 lbs., and in cupolas about 10 tons of metal can be melted per ton of fuel consumed. These economies have been largely due to the increased use of coke instead of the original anthracite fuel, and the author considers this material at some length. Coke, he observes, is a manufactured product, and consequently subject to many irregularities. These are due to the following causes:—1. The

* February 1, 1893, *Iron Age*, vol. li. pp. 246-247.

general character of the coal of the region used in its manufacture. 2. The character of the particular coal used, if in its normal condition or reduced in value by sulphur, slate, or ash. 3. The burning of the coal into coke after being tipped into the ovens. 4. The amount of water absorbed through weathering.

Coking coals exist in Pennsylvania from the East Broad Top region to the Ohio border. They include semi-bituminous coals, carrying a minimum quantity of about 15 per cent. of bitumen or volatile matters; mountain coals with about 20 per cent. of volatile matter, and the Pittsburgh seam, which embraces the Connellsville and gas coals, carrying the maximum amount of about 30 to 35 per cent. of volatile matter. Coke from all these regions is used by foundrymen, but that from each region has its own peculiarities, the best coke being made from the coal found in the eastern portion of this region, the coke gradually becoming of poorer and poorer quality as one proceeds westwards. Good results, either in the blast-furnace or in the cupola, can only be obtained with coke of good quality, and buyers ought always to make a personal examination of every waggon-load they purchase. If the general character of the coal from which the coke is made is slaty, the cross fracture of the coke will always show the presence of any slate the coal may have contained. If the slate only occurs in very minute particles, the purchaser has no just cause for complaint; but if it occurs in pieces of larger size, the coke should be rejected. Nearly all fuel contains from 8 to 10 per cent. of ash. The advantage which coke possesses as a fuel over anthracite lies in its much greater porosity, and consequent combustibility and reducing powers. Coke may be made from anthracite, but not commercially. Thus, the author made a series of experiments which showed that by mixing anthracite culm with 20 per cent. of raw tar an excellent hard coke resulted. Similarly, a good coke can be made from a mixture of one-half anthracite and one-half of a gas-coal, but the cost of manufacture is excessive. The author observes that the assay results of a coal should not show, as is at present customary, merely the percentage of volatile matter, but also the "bitumen" or tarry constituents, as it is on these that the value of the coal for coking purposes mainly depends.

Combustion at the Tuyere Level.—W. van Vloten* discusses the way in which the combustion proceeds immediately in front of the tuyeres in a blast-furnace. Many points, he observes, are in doubt.

* *Stahl und Eisen*, vol. xiii. pp. 26–30.

For instance, it is not known how far the oxygen of the blast penetrates into the furnace, whether the carbon of the fuel is at once completely converted into carbonic anhydride, or whether it is carbonic oxide that is produced. Then, again, the influence exerted by different temperatures of blast and by varying conditions in the nature of the fuel are still matters of doubt. With a view to elucidate this question, the author withdrew, by means of a cooled copper tube, portions of the gas both from the immediate vicinity of a tuyere nozzle and from various parts of the crucible portion of the furnace, both above and between the tuyeres. A drawing of the fusion zone of the furnace in which these tests were made accompanies the description. Most of the tests were made during the normal working of the furnace, which ran on basic Bessemer iron, the furnace having a daily out-turn of about 130 tons. For every 1000 parts of pig iron made there was charged on an average 920 to 940 parts of coke, containing 9·5 to 10 per cent. of ash, 600 parts of bulldog and scale, 1780 parts of ore, and 620 parts of flux. The blast was blown at a pressure of 5 lbs. through five tuyeres 4·72 inches wide in the clear, and at a temperature of from 650° to 750° C. Some of the tests were made when a grey basic Bessemer pig iron was being made which contained 2 per cent. of silicon. Of this metal the furnace made 100 tons a day, with a coke consumption of 20 cwt. per ton of pig iron made. The tuyeres were in this case 4·32 inches wide, otherwise the conditions were identical with those referred to above. Some other tests were made when the furnace was running on a white iron containing 5 per cent. of manganese. The results of the analyses are tabulated by the author, and they show that while the combustion is very intense, it is confined within a very small space. Despite the fact that the blast, on entering the furnace, had a velocity of 820 feet per second, the maximum distance from the tuyeres at which oxygen could be detected was only 2 feet. Various tests made at a distance of 24·8 inches above the tuyeres in no case showed any free oxygen. The results further showed that, even when using blast of a very high temperature, the oxygen of the blast was first converted into carbonic anhydride before any carbonic oxide was formed. Oxygen and carbonic oxide together were only found in three of the forty-six experiments the results of which are tabulated, and even then only in very small quantities. It is otherwise with hydrogen, the presence of which was observed in every instance, even when much free oxygen was also present. The ratio observed between oxygen and nitrogen was never identical with that existing between these gases in air, the oxygen being always present in

smaller quantity, due no doubt to the oxidation before the tuyeres of elements other than carbon—such, for instance, as silicon, manganese, iron, and phosphorus. Indeed, it may be considered that in the crucible portion of the blast-furnace there is an oxidising zone immediately in front of the tuyeres and a reducing zone directly above this oxidising one. The author further shows that the sinking of the charge in the blast-furnace is probably a very irregular movement, and to this he attributes the hanging of charges.

The Hanging of Charges in the Blast-Furnace.—M. Krawtzoff,* in abstracting the remarks of W. van Vloten † on the hanging of charges in the blast-furnace, describes the application of cold-blast for remedying this at the furnaces at Isbergues. The burden and materials had been in nowise changed when scaffolding began. For twelve days the usual means of alternately blowing, resting, increasing the pressure and number of tuyeres, had been adopted, with the result that the furnace became thoroughly congested. It was then determined to blow with cold air, and after four hours matters improved considerably. The first two casts were white iron.

G. Duvaux ‡ also describes his experience in the use of cold-air blast in the case of scaffolding, and adversely criticises the explanation of the action given by Van Vloten. He has only noticed scaffolding when the furnace runs on forge pig iron after long stoppage. When making foundry pig iron the slag contains :—

SiO_2	CaO	Al_2O_3
29	40–41	26

When the production is slowed down, the temperature of the blast increases, and the slag then becomes more refractory as the silicon goes into the iron. On using cold blast the silica is kept in the slag, which is then more easily fusible.

A Blast-Furnace Bear.—W. van Vloten § gives the following analysis of thin plates of metal observed in a blast-furnace bear, as showing that in the neighbourhood of the tuyeres the pig iron must be subjected more or less to a refining action by the oxygen of the blast :—

Carbon.	Silicon.	Manganese.	Phosphorus.
0·04	0·10	0·41	0·99

* *Revue Universelle des Mines*, vol. xxi. pp. 66–73.
† *Journal of the Iron and Steel Institute*, 1892, No. I., p. 396.
‡ *Revue Universelle des Mines*, vol. xxi. pp. 327–330.
§ *Stahl und Eisen*, vol. xiii. p. 29.

Opening the Taphole of a Blast-Furnace.—At the blast-furnaces of the Maryland Steel Company the rock-drill has been used with considerable success in opening the taphole of the furnace. According to Mr. D. Baker,* this application not only saves a considerable amount of labour, but it also does the work more efficiently. At first some difficulty was experienced owing to burning the bits, but the methods now adopted of mounting and working the drill have overcome this drawback. The drill is mounted on a cross-bar which slides on two vertical bars attached to the columns, and the cross-bar is connected to balance weights, so that it can readily be moved into or out of position. The drill employed has a feed long enough to enable it to penetrate the clay stopping, and to allow it to be speedily retired; this is done by a steam-cylinder at the rear of the drill. Both the front and back of the cylinder are open to steam-pressure, the rear end of the piston having a larger area, and the piston sliding through a friction-clamping device which regulates the feed. When the drill is to be withdrawn, the clamp is released and a valve opened to exhaust the rear end of the cylinder, so that the drill is rapidly drawn back. The machine-drill is quicker and cuts a better hole than the hand-drill, and the tapping hole stands longer. The drill can also be dismounted and used for other purposes.

Titaniferous Ores in the Blast-Furnace.—After describing, at some length, what was perhaps the first successful use of titaniferous ores with 18 to 20 per cent. of titanic anhydride in the United States by the Adirondack Iron and Steel Company between 1848 and 1852, Mr. A. J. Rossi† proceeds to a general discussion of the use of such ores in more modern practice. It is, of course, well known that they have been used in Sweden for a long time, and Swedish ironmasters have more than once expressed their surprise at the manifest reluctance of other smelters to employ this class of ore. Titaniferous ore yields a most excellent iron, and the general absence of deleterious amounts of phosphorus renders it suitable for steel-making. Indeed, such ore has been considered an antidote for cold-shortness. The general objections to the use of titaniferous iron ore may be stated under three heads: 1. The tendency toward the formation of infusible compounds of titanium, carbon, and nitrogen. 2. The refractory character of the ore, necessitat-

* *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

† *Ibid.*, Montreal Meeting (advance proof).

ing a greater consumption of fuel and a higher temperature. 3. The viscosity of the slags, with the danger of stopping the flushing-hole.

In support of the view that there are immense deposits of ore in the United States which, while containing from 3 to 4 per cent. of titanic anhydride, are remarkably free from silica, the author quotes fifteen analyses of various ores that show little or no silica and from 52 to 68 per cent. of metallic iron. Perhaps the most famous of all the beds of titaniferous ore in that country are in the Adirondacks, where enormous deposits occur, with iron from 50·15 to 65·45 per cent., titanic anhydride from 10·91 to 25·78 per cent., silica about 1 per cent., and small quantities of alumina, lime, and magnesia. It would thus be entirely feasible to secure ore practically free from silica, and the question of fluidity of slag would rest with the possibility of slagging the titanic anhydride.

The Desulphurisation of Iron.—In addition to the papers read by Mr. Stead and Mr. Saniter before the Institute, and published in the present and preceding volumes,* Mr. Saniter has also communicated papers to other societies,† giving the intermediate history of the process. It has been found that sulphur can be removed without affecting the silicon in the metal if the mixture of lime and calcium chloride is thoroughly dried before use. If, however, the mixture is used in the wet state, the silicon is also eliminated to an extent which can be controlled by the operator. The proportions of the mixture are varied, according to the temperature of the iron, more calcium chloride being used to render the mixture more fusible if the iron is cold. An account is also given of the method of using the process at the Wigan Coal and Iron Company's works, and the alterations required for it. A large number of analyses and other details of the metal are also given. It is pointed out that this process can speedily be put into use when it is evident from the slag that the metal is rich in sulphur. Further experience has confirmed the fact that the linings and brickwork of the furnaces, ladles, and regenerators are not deteriorated by the mixture.

Referring to remarks on this process by E. Stead, G. Hilgenstock,‡ of the Hoerde Works, adversely criticises Saniter's process, giving the results of the following test in proof of his statement. Some metal was melted and poured into a ladle containing Saniter's mixture, with the

* *Journal of the Iron and Steel Institute*, 1892, No. II., p. 216.

† Papers read before the Cleveland Institution of Civil Engineers, December 19, 1892, and before the South Staffordshire Institution of Iron and Steel Works Managers, January 14, 1893.

‡ *Stahl und Eisen*, vol. xiii. p. 168

result that the percentage of sulphur was reduced from 0·409 to 0·329, a charge in which none of the Saniter mixture was employed showing a diminution in the sulphur from 0·62 to 0·51. The process, in Mr. Hilgenstock's opinion, is not satisfactory, and he attributes the desulphurisation when observed to the presence of considerable quantities of manganese in the metal.

These results were discussed in one of the technical journals by Mr. Stead,* as well as in his paper in the present volume, which also deals with the adverse arguments not mentioned above.

Mr. F. J. R. Carrulla † also refers to the Saniter process for desulphurising iron, and mentions the absence of skull as possibly being due to the combustion of the silicon.

The Manufacture of Spiegeleisen and Ferromanganese.—A short account of the history and manufacture of spiegeleisen and ferromanganese, together with a number of analyses of the materials employed and the products, is given by Mr. J. D. Weeks and Mr. G. L. Stone.‡ The chief difficulty in the production is the regulation of the temperature of the blast, which should be at about 1200° F. If it is higher, silicon is reduced, and in any case the lining of the furnace is worn out very quickly. One-fifth to one-third of the manganese in the ore is wasted in the slag and fume. Coke is the best fuel, 4800 to 5000 lbs. per ton being used, the higher quantities for the richer products. Modern furnaces produce 230 to 250 tons per week of ferromanganese, containing 78 to 84 per cent. of manganese. A highly basic slag, good fuel, and slow working are necessary. Furnace B of the New Jersey Company is 34 feet 9·5 inches in height, diameter at boshes 8 feet, hearth 5 feet, stock line 6 feet, bell 3½ feet. Cooling plates are used, and the lining is 14 inches thick. The blast is 4000 cubic feet per minute, at 3 to 5 lbs. pressure, heated to 950°. The furnace above the stock line is closed by hinged cast iron doors, and openings are also provided round the hopper to aid in clearing away any accretions of zinc oxide. Their A furnace is similar, but 6 inches wider at the stock line and hearth, and the lining is much thicker. The Passaic Zinc Company's furnace is radically different. The boshes are very high, and both boshes and hearth are much wider in proportion to the height. The furnace of the Lehigh Zinc and Iron Company is much

* *Iron*, vol. xli. pp. 117–118.

† *Industries*, vol. xiii. p. 645.

‡ *Report of the Mineral Industries in the United States at the Eleventh Census*, 1890, pp. 323–329.

like that of the New Jersey Company, but the entire bell and hopper can be removed to one side. The following table gives a comparison of the work of these furnaces for the years 1889 and 1890:—

	New Jersey.		Passaic.	Lehigh.
	A.	B.		
Cubic feet in furnace to stock line	1243	1134	1443	1545
Iron made per day, tons	9·36	9·14	12·38	9·45
Cubic feet per ton of iron per day	133	124	116	163
Yield of slag, per cent.	31·36	30·34	31·86	35·48
Fuel per ton of iron, tons	2·57	2·66	2·53	2·84
Limestone, per cent.	23·60	23·80	29·10	56·00
Stock per day per 100 cubic feet, tons	4·95	5·44	5·72	4·44
Approximate weight of slag per ton of iron, tons	2·34	2·44	2·34	2·47

Analyses of the slags were as follows:—

Silica	35·77	20·14	18·43	27·66	25·13
Alumina	11·67	4·44	8·65	...	...
Oxide of iron	2·09	31·37	30·13	35·77	33·24
Oxide of manganese	9·51	15·96	13·18	13·46	13·47
Oxide of zinc	...	3·76	4·43	5·93	5·63
Lime	30·36	15·61	14·67	...	...
Magnesia	10·39	2·59	3·20	...	...

Two analyses of spiegeleisen made by the New Jersey Company were:—

Manganese.	Iron.	Silicon.	Phosphorus.	Carbon.
11·59	83·25	0·37	0·20	4·63
11·67	83·23	0·99	0·19	4·02

The Manufacture of Manganese and its Alloys Free from Carbon.—In the course of an account of the Greene-Wahl process for manufacturing manganese and alloys of manganese free from carbon, Mr. F. L. Garrison* gives a historical summary of the manufacture of spiegeleisen and ferromanganese, and of the numerous attempts to manufacture manganese in a state of purity, and more or less free from carbon. Most of the methods used fall into two groups—the reduction of oxides or carbonates by carbon and of the chlorides or fluorides by sodium. By the latter methods manganese free from carbon may be produced, but at a considerable cost. Electrolytic methods have also been used, but necessitate the use of carbon electrodes, and the conse-

* *Transactions of the American Institute of Mining Engineers*, Montreal Meeting (advance proof).

quent production of carbides of manganese. Fusion of the carbides of manganese with oxides of the metal is not found to remove the carbon, and this may be explained by some experiments by Guntz, who shows that carbonic oxide is reduced by manganese at a red heat. Messrs. Greene and Wahl have found that magnetic separation will not remove iron from manganese ores, on account of the intimate admixture, but that a 30 per cent. solution of sulphuric acid will remove the iron. As a rule, however, it is not necessary to do this. For the reduction of the manganese the haloid compounds have been found too expensive, but the oxides can be used. Graphite crucibles lined with magnesia made by calcining magnesite are used for the reduction, and with this lining contact with carbon is avoided. The reducing agent employed is aluminium, and the manganese monoxide forms the source of the metal. This oxide is prepared by heating the dioxide in a stream of reducing gas for about an hour, and allowing it to cool in the gas. It is then mixed with the calculated quantity of aluminium, which is preferably granulated, and some lime and fluorspar flux. At a red heat the reaction commences, and proceeds with great energy and the evolution of a large amount of heat. The temperature attained is so great that the manganese is fused, and the metal can be poured if it be done quickly. The ordinary yield is 2·5 to 2·6 parts of manganese for one of aluminium on a small scale; but as much as 2·84 parts, or 94·5 per cent. of the theoretical yield, has been obtained. The cost of production at the rate of two tons weekly is given as 17d. per lb., but the price is largely dependent on that of aluminium.

This process is also described by Messrs. W. H. Greene and W. H. Wahl.*

The Reduction of Nickel, Chromium, and Manganese.—H. Moissan † states that by the reduction of oxides by carbon in the electric furnace, he has obtained in this way alloys containing—

	I.	II.	III.	IV.
Nickel, per cent. . . .	85·00	85·82	90·60	94·06
Carbon, per cent. . . .	14·59	13·98	10·20	6·35

A sample of cobalt reduced in the presence of a large excess of oxide contained 0·73 per cent. of carbon.

Pure manganese oxide was mixed with coke, and a current of 300

* *Journal of the Franklin Institute*, vol. cxxxv. pp. 218–223.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxvi., No. 8.

amperes and 60 volts passed through. It yielded in the presence of an excess of coke alloys containing—

	I.	II.	III.	IV.
Manganese, per cent. . .	85·00	85·82	90·60	94·06
Carbon, per cent. . . .	14·59	13·98	10·20	6·35

When, however, there was an excess of the oxide, the percentage of carbon did not exceed 4 or 5. When the percentage of carbon is high, the alloy is rapidly attacked if exposed to ordinary atmospheric action. Small fragments placed in water were decomposed in the course of twenty-four hours, yielding a gaseous mixture of hydrogen and hydrogen carbides.

Although under ordinary circumstances the reduction of chromium oxide by carbon is much more difficult to effect than in the similar reduction of manganese oxide, yet in the electric furnace less than ten minutes is required to effect the reduction, if the current available is of the strength of 350 amperes and 50 volts. A perfectly melted alloy is obtained in this way. Using varying percentages of oxide and carbon, the author obtained alloys containing—

	I.	II.	III.	IV.
Chromium, per cent. . .	87·37	86·25	90·30	91·70
Carbon, per cent. . . .	11·92	12·85	9·47	8·60

By melting these alloys in contact with chromium oxide the whole of the carbon can be burnt out. A current of 30 amperes and 50 volts produces the same results as the current previously referred to, but in four times the time.

Blowing-Engines at the Newport Ironworks.—Mr. T. Westgarth * describes the alterations made in three of the blowing-engines at the Newport Ironworks to obtain more power from the steam. There were five engines giving blast at an average of 4 lbs. pressure to five furnaces, yielding 2780 tons per week. When two furnaces were put on to hæmatite, it was found that more power was required than was available, so it was determined to compound the three engines, which had the following dimensions :—

	I.	II.	III.
Diameter of steam-cylinder, inches . . .	35	40	35
Diameter of air-cylinder, inches	78	78	78
Stroke, inches	48	48	48

* Paper read before the Cleveland Institution of Engineers, April 10, 1893.

The plan ultimately adopted was to blow three of the furnaces by separate engines, which were to be entirely separate and self-contained with their own condensers and air-pumps. No. I. engine was fitted with two new cylinders, 28 and 48 inches in diameter; No. II. with a high-pressure cylinder 28 inches in diameter, the existing cylinder being used as the low pressure; and No. III. was fitted with a condenser and air-pump without altering the cylinder. This made two compound condensing and one high-pressure condensing engine, instead of three high-pressure engines. The high-pressure cylinders have piston-valves. The condensers and air-pumps are fitted on the upper platform, and driven from the main crossheads. Jet condensers are used, and the air-pumps were ultimately made single-acting. The condensers can be cut out in case of necessity. At the present time the engines are giving an average blast-pressure of 5½ to 6 lbs., and although only four of the furnaces are at work, two on hæmatite, the actual output is 2720 tons, against 2780 tons before the alterations with five furnaces at work. It is now only necessary to use seventeen boilers against the previous average of twenty and a half. Some discussion ensued on the relative advantages of surface and of jet condensers with regard to the question of dirty condensing water.

German and Austrian Blowing-Engines.—With a view to obtain accurate information relating to the construction and working of blowing-engines used at the blast-furnace and Bessemer works in Rhineland-Westphalia, Upper Silesia, and Austria-Hungary, A. von Ihering* has collected from the directors of the various works full details relating to the subject. The statistics are printed in tabular form, and cover more than fifty pages. Particulars are given of 227 engines at eighty-four works. The distribution of the blast-furnace blowing-engines is as follows:—

Country.	No. of Works.	No. of Engines.
1. Rhineland-Westphalia . .	24	94
2. Austria-Hungary . . .	27	59
3. Upper Silesia	9	38
Totals . .	60	191

Classified according to their construction, the engines are as follows:—

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 381-452.

Country.	No. of Works.	No. of Engines.
A. *Beam-Engines.*		
1. Rhineland-Westphalia . .	6	13
2. Austria-Hungary . . .	4	6
3. Upper Silesia	4	6
Totals . .	14	25
B. *Vertical Engines.*		
1. Rhineland-Westphalia . .	17	40
2. Austria-Hungary . . .	12	19
3. Upper Silesia	9	28
Totals . .	38	87
C. *Horizontal Engines.*		
1. Rhineland-Westphalia . .	19	41
2. Austria-Hungary . . .	15	25
3. Upper Silesia	3	4
Totals . .	37	70

The total number coming under these classes is thus 182. The nine engines wanting are not included, inasmuch as they are driven by hydraulic power.

From these statistics the following rough generalisations may be deduced:—Beam-engines are in a decided minority, vertical engines predominating. The number of the former is about 28 per cent. of the latter, and about 35 per cent. of the horizontal engines. The ratio of the horizontal to the vertical engines is approximately 8 to 10. The number of vertical and of horizontal engines is the same in Rhineland-Westphalia, but in Austria-Hungary the horizontal engines predominate, whilst in Upper Silesia the vertical ones are preferred.

The tables give the names of the ironworks, the makers of the blowing-engines, details of the engines, such as the diameter and stroke of the steam-cylinder and of the blowing-cylinder, the steam-pressure, the air-pressure, quantity of steam, quantity of air, horse-power, number of revolutions per minute, dimensions and weight of the fly-wheel, price and weight of the engine, velocity of the piston, and the date of the construction of the engine.

Hot-Blast Stoves.—The Hugh Kennedy hot-blast stove is described by Mr. W. C. Coffin * as following the general lines of the Whitwell stove, with the blast connections unaltered, but gas is introduced at the

* *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

bottom of each pass. Outlets are provided at the top, so that the gases have a direct natural draught in each pass, and the highest heats are obtained at the bottom instead of the top. As the natural tendency is to the reverse of this, the brickwork soon acquires an almost uniform temperature. These stoves have been in use for two years with satisfactory results. They can be kept very free from dust and slag, and as there are several combustion chambers, an excessive heat is not generated.

A lengthy discussion ensued, in which the relative merits of iron and of brick stoves were considered. Mr. E. S. Cook stated that these Kennedy stoves have been put up at the works of the Warwick Iron Company, which had been considered the stronghold of iron stoves. At these furnaces it was necessary to almost entirely replace the Durham iron pipe stoves, so, after considering the merits of various types, Mr. Cook and Mr. Birkinbine settled on the Kennedy stoves. At the time, three 20 by 60 feet stoves had been at work for a fortnight, and they appeared to be economical of gas, and to be easily controlled. The stoves are two hours on gas and one hour on blast, at 15,000 cubic feet per minute, at a temperature below 1200°, the drop seldom exceeds 30°.

Mr. N. B. Wittman, with blast-furnaces using anthracite, found a decided increase in production since brick stoves have been installed, and in many weeks the fuel rate was less, but there has been much more variation in the grade of the iron, and, on the whole, but a trifling economy of fuel. The question of the temperature of the escaping gases was referred to by several speakers, and Mr. R. W. Raymond discussed the question at some length, and drew the distinction between efficiency and business economy. Up to the present time, the technical superiority of the brick stove has not been established at anthracite furnaces, but theoretically it would seem to be the best with its wide range of temperature, although an iron stove might still be selected. The effective life of neither the iron stove nor the brick stove has as yet been worked out. The duration of a stove, in terms of the tonnage of the product, has also to be considered. In the Durham iron stove and in the Kennedy brick stove there is a considerable loss of heat, but in the former stove other considerations outweighed this loss, and so it may be with the brick stove. Mr. Morris pointed out that the interest on a new investment has sometimes to be neglected in order to be in a position to compete. With brick stoves and the ready alterations in the temperature of blast available, it is found possible to average the silicon in the iron at 0·30 and

the sulphur at 0·03. Very little is made above 0·40 and 0·04. The costs of iron and brick stoves were also mentioned by Mr. Cook and Mr. Fackenthal. Mr. Birkinbine also referred to the selection of brick stoves for the Durham furnaces, and describes the careful and solid way in which they were built. Unless a good price for a thorough equipment were paid, he would still recommend iron stoves, and has recently put up both in the same district. In a further communication, Mr. Fackenthal referred again to the costs as presented by others, and remarked on the state of repair in which the Durham stoves were maintained. In one case two anthracite furnaces were worked under similar conditions with iron and brick stoves respectively, but with no advantage on either side. Mr. A. Weimer described a form of stove designed in 1884, and similar to the Kennedy stove, but it has not been put into use.

Mr. E. A. Cowper* describes the application of the Cowper stoves to chemical industries. A description of the stove and the method of working it is given, and it is pointed out that the air current may be supplied by a blowing-engine, fan, or steam jet, according to the amount of air required. For chemical purposes the stove may be used as a store of heat, and to supply air of any desired temperature if a by-pass is used. The various applications are then dealt with.

Phosphorus in the Blast-Furnace.—N. Kjellberg† has made a number of experiments with a view to ascertain the exact behaviour of phosphoric acid in the blast-furnace. He finds that if the percentage of phosphoric acid in the ore does not exceed about 1·25 per cent., then the slight variation in the temperature of the furnace that he observed did not appreciably affect the degree of reduction of the phosphoric acid. Similarly, the influence exerted by differing acidity of the slag appeared without marked influence, by far the greater part of the phosphorus contained in the ore passing into the pig iron produced. Indeed, only from 5 to 10 per cent. of it passed into the slag. If, on the other hand, the percentage of phosphorus exceeds 1·25, then a more marked division of the phosphorus between the pig iron and the slag appears to commence, the degree in which the phosphorus is slagged off increasing with the percentage present in the ore. Both the temperature of the furnace and the degree of acidity of the slag begin then to exert marked influence on the reduction of the phosphoric acid, and this action, too, increases with the increase in the percentage of phosphorus in the ore. Even

* *Journal of the Society of Chemical Industry*, vol. xii. pp. 311-314.
† *Jernkontorets Annaler*, vol. xlvii. pp. 180-193.

if the percentage of phosphorus in the ore reaches 3·6, the larger percentage of the phosphorus still passes into the iron and the smaller into the slag. With this percentage, however, it is possible, by using heavy ore charges and a basic slag, to flux off from 40 to 50 per cent. of the phosphorus. With a high temperature and acid slag the phosphorus passes into the iron. A volatilisation of phosphorus out of the blast-furnace does not appear to take place in the case of ores containing up to 3·6 per cent. of phosphorus.

The percentage of carbon that is contained in phosphoric pig iron diminishes as that of the phosphorus also present increases, but this influence of the phosphorus does not appear to exert itself until the phosphorus reaches 3 per cent. The two most phosphoric ores employed in the furnaces during the period of the author's tests contained respectively 2·6 and 3·6 per cent. The pig irons that were made from these ores usually contained but very little graphite. They were quite white, with large specular facets, resembling those of spiegeleisen. As the percentage of phosphorus present in the pig iron increases, that of silicon diminishes, and finally practically no silicon will be present at all. Thus, a charcoal pig iron which contains over 4 per cent. of phosphorus as a rule contains no more silicon than a steel, and it is only possible to force a few tenths per cent. of silicon into the pig iron by the addition of much quartz, and by employing a very acid slag. Those pig irons which were richest in phosphorus proved to be extremely brittle.

The author has found that iron ores containing respectively 0·25, 0·50, 0·75, and 1·00 per cent. of phosphorus, together with 50 per cent. of iron, gave in the blast furnace a pig iron containing respectively about 0·50, 1·00, 1·40, and 1·90 per cent. of phosphorus. If it is desired to make from a 60 per cent. ore in an ordinary charcoal-furnace a pig iron suitable for the basic open-hearth process, and containing not more than 0·6 per cent. of phosphorus, the ore must not contain more than 0·4 per cent. of that element. For foundry pig iron with up to 1 per cent. of phosphorus, a 60 per cent. ore must not contain more than 0·6 per cent. of phosphorus, while when it is desired to produce basic Bessemer pig iron with at least 2 per cent. of phosphorus, the ore itself, if of the above percentage of iron, must contain at least 1·6 per cent. of phosphorus, assuming that about 75 per cent. of the phosphorus is reduced.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Non-uniformity of Iron from One Cast.—Mr. M. Stevens * gives analyses of pig iron taken from the different beds in one cast, with the character of the pig iron in each case. No. 1 is the bed farthest from the furnace. In a cast of twenty-eight tons of grey forge iron the silicon contents were as follows :—

Number of bed . .	1	2	3	4	5	6	7	8	9	10	11	12	13
Silicon, per cent. . .	1·58	1·62	2·11	2·50	2·50	2·57	2·72	2·92	2·55	2·06	1·80	1·78	1·80

In a second cast of twenty tons of grey forge iron, the results of the analyses were as follows :—

No. of Bed.	Silicon.	Phosphorus.	Manganese.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	1·736	0·727	0·473	0·058
2	1·908	0·737	0·473	0·071
3	1·806	0·716	0·473	0·071
4	1·876	0·723	0·473	0·060
5	2·006	0·736	0·489	0·071
6	1·927	0·729	0·489	0·071
7	1·768	0·701	0·489	0·046
8	1·764	0·702	0·489	0·058
9	1·745	0·686	0·489	0·060
10	1·554	0·654	0·473	0·066

In the latter case the character of the pig iron was as follows :—1 and 2, close iron, very even grain, not mottled on edges of pig, good colour; 3 and 4, hard, medium iron, running from close on edge of pig to good medium in centre, good colour; 5, medium iron, close and open, thoroughly mixed, medium colour; 6, medium iron, upper two-thirds of pig medium grain, lower third close, medium colour; 7 and 8, medium iron, upper half of pig medium grain, lower half close, medium colour; 9, medium iron, upper half of pig medium grain, lower half close and medium mixed, close spot in centre, medium colour; 10, close iron, running from mottled on edges of pig to fair grain in centre, medium colour.

The phosphorus follows the silicon, whilst the manganese and sulphur do not vary greatly. The silicon preponderates near the middle of the cast. Previous investigators have found different results, for Mr. Thomas found the first and Mr. Brown the last beds to show most silicon.

* *Engineering and Mining Journal*, vol. liv. p. 558.

Austrian Pig Iron.—Dr. E. Prziwoznik * has published the results of a series of analyses of Austrian pig iron. Amongst these are the following:—

Description.	1.	2.	3.	4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Combined carbon	3·41	3·42	4·49	4·74
Silicon	0·28	0·16	0·28	0·83
Phosphorus	0·07	0·09	0·73	0·14
Sulphur	0·03	0·03	0·01	0·01
Manganese	1·10	0·86	12·91	13·10
Cobalt	trace	trace	trace	...
Copper	trace	trace	trace	0·11
Iron	95·11	95·44	92·23	81·07

White pig iron (1) from the Austrian Alpine Company's Works; (2) from Eisenerz; (3) spiegeleisen from Eisenerz, and (4) from Witkowitz.

Description.	5.	6.	7.	8.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Combined carbon	0·850	0·540	0·310	2·324
Graphite	3·160	2·700	2·950	0·221
Silicon	1·229	2·373	1·540	0·094
Phosphorus	0·093	0·057	0·165	0·089
Sulphur	0·018	0·022	0·025	0·090
Manganese	3·099	3·520	3·856	1·497
Copper	...	0·025	0·003	trace
Iron	91·551	90·763	91·151	95·685

Grey pig iron (5) from Vordernberg; (6) from Mariazell; (7) from Schwechat; (8) from Hieflau.

Analyses of Basic Bessemer Pig Iron.—The following are analyses showing the average composition of the basic pig iron used at the works named:†—

Works.	C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Longwy	...	0·35	1·80	2·0 to 2·25	0·05
Angleur	...	1·00	1·50	2·00	0·05
Hörde	3·60	0·58	1·37	2·75	0·08
Phœnix	2·80	0·20	1·8 to 2·3	2·0 to 2·40	0·05
Peine	3·60	0·60	2·25	2·70	0·05
Kladno	...	0·44	0·40	2·00	0·03

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 466–469.

† *Stahl und Eisen*, vol. xiii. p. 105.

At the Kladno works the pig iron is melted in an open-hearth furnace. It is white, but in consequence of the large quantity of fuel used in melting it, is afterwards very hot.

The percentage of silicon in basic Bessemer pig iron may vary from 0·2 to 1·0 per cent., or even more, but it is best to keep it low, as the lining otherwise will suffer severely. If the percentage of silicon is less than 0·7, and if the metal is not taken direct from the blast-furnace, a coke of the best quality must be used when melting it in the cupola, or the charges will otherwise work very cold. In this latter case the percentage of manganese must be largely increased, and it must exceed 2 per cent. if the percentage of silicon is less than 0·4. With direct metal from the blast-furnace, the percentage of silicon may be lower than is otherwise admissible, as such metal with normal furnace working is always very hot.

Steel cannot contain more than 0·1 per cent. of sulphur without showing a tendency to work badly. A basic pig iron may then theoretically contain up to 0·1 per cent. of sulphur if it is to be re-melted in a cupola, as when this is done, and the coke used is freed from sulphur, the percentage of sulphur in the metal is slightly diminished, and in the basic converter itself a slight diminution in the percentage of sulphur is also effected, but the pig iron must be high in manganese. When using direct metal, the percentage of sulphur it contains must be less than 0·1. When the pig iron contains no more than 0·06 per cent. of sulphur, its use is never dangerous.

The percentage of phosphorus in basic Bessemer pig iron varies as a rule between 1·80 per cent. and 2·40 per cent. With the lower limit of phosphorus at least about 1 per cent. of silicon must also be present, the pig iron must be either very mottled or even grey, and be also very rich in manganese, from 1·75 to 2·0 per cent., as the blow might otherwise be extremely cold. A good composition is 2·30 per cent. phosphorus, 0·70 silicon, and 1·60 manganese. The phosphorus may exceed 2·30, but in that case the bath should be cooled by the addition of scrap or a larger charge of lime, and the percentage of manganese must be high.

The percentage of manganese should never be less than 1·5, and 1·75 is a good average, and when an exceptionally good product is to be made the percentage should be kept still higher.

The carbon should be present in about the proportion existing in mottled to grey pig iron showing graphite. The presence of graphite in the pig iron always leads to an improvement in the quality of the ingot

metal. Such metal is very easily blown, and the converter lining suffers but little.

The Best Foundry Iron.—The Valentine Iron Company, of Bellefonte, Pennsylvania, has been making a wide series of experiments to arrive at the best all-round iron for foundry practice.* As the results of these experiments the following is given as the range within which the pig iron should run, varying somewhat for light or heavy work:—

Silicon.	Graphitic Carbon.	Combined Carbon.	Manganese.	Phosphorus.	Sulphur.
2·50 to 3·75	2·75 to 3·25	0·25 to 0·75	0·30 to 0·70	0·40 to 0·80	not over 0·06

Some of the finest machine-borings obtained from a sewing-machine company showed the analysis of the casting to be as follows:—

Silicon.	Graphitic Carbon.	Combined Carbon.	Manganese.	Phosphorus.	Sulphur.
2·82	3·36	0·16	0·67	0·60	0·05

A recent experiment made by the company shows the chemical change which takes place in the cupola. In this instance the melt was made with a 48-hour coke having 1·46 per cent. of sulphur—too high. This will explain the increase of sulphur in the casting. The annexed table shows the analyses of the pig iron used, and of the resulting castings—one a heavy piece of machinery and the other a thin plate $\frac{1}{16}$th of an inch in diameter:—

Description.	Pig Iron.	Large Castings.	Small Castings.
	Per Cent.	Per Cent.	Per Cent.
Silicon	2·680	2·610	2·380
Graphitic carbon	3·140	3·420	2·980
Combined carbon	0·740	0·100	0·430
Manganese	0·654	0·397	0·490
Phosphorus	0·508	0·530	0·502
Sulphur	0·041	0·089	0·087
Iron	92·230	92·850	93·130

Mr. C. Jones† considers the general characteristics of pig iron and its grading. He gives the following as a typical Pennsylvania foundry pig iron:—

Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.
3·75	0·20	2·50	0·75	0·30	0·06

* *Iron*, vol. xli. p. 384.

† *Iron Age*, vol. li. pp. 180–182.

As illustrating the effects of melting pig iron in a cupola, he gives the following analysis:—

Description.	Original Pig Iron.	Castings.
	Per Cent.	Per Cent.
Carbon	1·61	1·65
Silicon	0·98	0·61
Phosphorus	1·37	1·25
Sulphur	0·16	0·29
Manganese	0·12	0·47
Calcium	0·40	0·81
Magnesium	0·29	0·43
Totals	4·93	5·51
Iron	95·15	94·42
Totals	100·08	99·93

The effect of the various elements present in the metal is also briefly considered.

Irregularity of Manganese in Ferromanganese.—The ferromanganese used for examination by Professor W. Hampe * consisted of a fragment of a pig from the Dortmunder Union. On top, underneath, in front, and on the left side, the piece showed the natural cast surfaces; behind and on the right side, however, fracture surfaces. It was very rich in manganese. On a part of the upper surface were crystal-needles. The piece was bored at three different points, the borings being collected. Two specimens were taken from the first bore-hole, namely, No. 1 from the upper surface and No. 2 from the lower part. Altogether four samples were obtained, each of which was carefully tested for manganese by two separate chemists, with the following result:—

	Average Percentage.
No. 1	82·82
No. 2	81·97
No. 3	81·10
No. 4	80·17

The percentage of manganese is therefore highest in the upper layers where formation of crystals had taken place. Farther down the percentage decreased. No. 2, from the same bore-hole, but from 0·59 inch downwards to 0·98 inch, from the non-crystalline portion, contained

* *Chemiker Zeitung*, vol. xvii. p. 99.

0·85 per cent. less manganese than No. 1. Still poorer (by 0·87 per cent.) is specimen No. 3, taken from the front side (cast surface). On the manganese contents of this specimen, No. 4, from the opposite side (fracture surface), bored at almost the same height, shows a decline of 0·93 per cent.

Ferromanganese and Ferro-silicon from Witkowitz.—Samples of these materials made at this Austrian works have been found to contain :*—

	Mn.	Si.	P.	C.
Ferro-manganese . . .	83·09	...	0·027	...
Ferro-silicon . . .	2·95	12·22	0·232	2·936

Ferro-tungsten.—Mr. W. H. Wahl† has examined a series of tungsten alloys possessing considerable hardness and toughness, an extremely fine crystalline texture, and a specific gravity ranging between 9·3 and 10·14. Some of the fractures exhibited the fact that the alloy was not homogeneous, the presence being observed of what are apparently smooth cleavages of imperfect crystals scattered through the finely crystalline matrix of the alloy. A sample of the alloy of 10·14 specific gravity exhibited on analysis a very high percentage of tungsten, and its behaviour towards liquid and fused solvents proved the interesting fact that a large proportion of the tungsten was present in the uncombined condition crystallised in the matrix of the alloy. The analytical results were as follows :—

C.	P.	Si.	Mn.	Fe.	W. (metal).	W. (alloy).
0·85	0·041	0·14	trace	42·28	22·54	34·35

Calculation shows that the figures representing the compound Fe_4W are almost identical with the ratio of the iron and combined tungsten, and this ratio appears to represent the saturation point of iron for tungsten.

III.—*FOUNDRY PRACTICE.*

Foundry Construction.—A series of drawings have been published‡ illustrating the plan and general construction and arrangements

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 21.
† *Journal of the Franklin Institute*, vol. cxxxiv. pp. 470–472.
‡ *L'Industria*, vol. vi. pp. 563–568.

of a foundry intended for the manufacture of small articles. The daily output is intended to be about thirty tons of castings. The plant is arranged to be served by two cupolas.

In an account of the Great Northern Railway Works at Doncaster, some description is given * of the foundry and pattern shop, together with plans and illustrations. Several hand-moulding machines are in use, but very few hydraulic machines. Some particulars are also given of the kinds of iron used and of the methods of casting, in a series of articles on the construction of the modern locomotive.†

The Grading of Pig Iron.—In discussing the grading of pig iron, especially of foundry pig iron, Mr. E. T. Clymer ‡ states that he believes that the grain of iron indicates with considerable accuracy the condition of the carbon in the pig—that is, to what extent it is in the combined or in the graphitic state—and that as regards other elements nothing can be told with certainty. Pig iron may contain sufficient quantities of most of the metals and metalloids to render it unfit for use in the foundry, without the fracture indicating their presence. In large quantities probably all the impurities of pig iron would make their presence manifest by changing the appearance of the fracture, but before the impurities manifest themselves in this way the iron becomes useless for foundry purposes. An exception to this statement may be made concerning silicon, which often causes a closeness of grain when over 3 per cent. is present in the pig iron, and yet for certain kinds of castings it is desirable to have iron containing a large percentage of this element. At the same time, consumers do not sufficiently understand the value to be attached to the various elements present, and it therefore seems impossible at present to establish any new method, based on chemical analysis, for the universal grading of iron. The manufacturers would, however, be pleased if the consumers of iron would recognise the fact that too much attention has been paid to fracture. More attention is paid to grain now than was the case ten years ago, as the fracture of every pig is now scrutinised, although there seems to be practical unanimity among all who have carefully examined the subject that the grain of foundry pig iron is not to be implicitly relied upon as an indication of its quality.

* *The Engineer*, vol. lxxiv. pp. 515–536.

† *Ibid.*, vols. lxxiii. and lxxiv. p. 333, &c.

‡ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

The First American Casting.—Mr. C. H. J. Woodbury * refers to the first American casting. This is an iron pot made at the Saugus Ironworks, Lynn, Massachusetts, in 1642. This pot was presented at the time to the then owners of the land on which the foundry had been erected, and has now been presented by a descendant to the city of Lynn. The original ironworks contained a blast-furnace, in which bog iron ore was smelted, with charcoal as a fuel and calcined oyster-shells as a flux. Castings were made directly from the metal flowing from the blast-furnace into a pool, whence it was dipped by crucibles and poured into the moulds. The ordinary cupola was not invented until 1790.

Machine Moulding.—The various improvements in moulding are shortly traced by Mr. H. Tabor,† and a reference is made to the neglect with which the foundry is treated as compared with the fitting-shop, where new machines are in constant use. There are now a number of moulding-machines in use operated by belts and cams, by hydraulic, pneumatic, and steam pressure. All ramming-machines may be said to have platens, of which there are two types, rigid and flexible. The latter yields to irregular depths, and exerts an even pressure over the mould. It is made in two forms—first the water bag, a box with a flexible bottom filled with water, and second a group of rammers independently hung on equalising levers. Owing to the friction of the sand on the sides of the flask, more pressure is required at the edges, and a series of experiments have been made by Mr. A. B. Moore to determine the friction in the sand itself and against the box. The author then gives a description of the Tabor moulding-machines, and discusses the question of their employment.

A New Method of Melting and Casting.—Mr. G. A. Poyson ‡ describes the Taussig process of melting and casting metals. The metal is melted by the electric arc in a vessel exhausted of air, metal electrodes being used. The moulds are also exhausted. Castings are said to have given good results.

* *Iron Age*, vol. l. p. 1104, with illustration.

† *Transactions of the American Society of Mechanical Engineers*, vol. xiii. pp. 537–556.

‡ *Iron*, vol. xli. p. 252.

PRODUCTION OF MALLEABLE IRON.

Native Manufacture of Iron.—Mr. H. L. Stokes* publishes a drawing of an iron smelting furnace used in the Mazoc Valley, Mashonaland. In many parts of the country are very skilful workers in iron. They melt the rich iron ore in furnaces by means of charcoal; the blast being obtained from double bellows made from the skins of kids. The blast-pipes are of clay, in lengths of 18 inches, and they fit telescopically into each other. Much ingenuity is shown in the construction of these small ironworks, and in the manufacture of weapons and agricultural implements.

Squeezing Machine.—The gradual displacement of puddled iron by steel has led to squeezing machines receiving less attention of recent years. A new form of squeezer is now illustrated. The machine is circular in form, and the arrangement is such as to greatly lessen the wear of the end of the wing shaft, to which the bevel gear is attached, the greatest cause of trouble in this form of squeezing machine.†

* *Westminster Gazette*, March 13, 1893.

† *American Manufacturer*, vol. lii. p. 627, with two illustrations.

FORGE AND MILL MACHINERY.

The Wittgenstein Rolling-Mill.—The use of small ingots has never proved profitable with either the basic Bessemer or the basic open-hearth processes, and large ingots have to be employed. In order to reduce ingots of such large size to finished sheets, powerful rolls are necessary. An ingot, too, gives such a large number of sheets that it is impossible to finish these in one heat, and it is a matter of absolute necessity to allow them to cool down. This is accompanied by many disadvantages as compared with the older methods of manufacture where blooms were used, and these are consequently still able to enter into competition with sheets made of basic metal. To meet this a new method has been introduced by C. Wittgenstein at the Rudolfshütte, near Teplitz. The idea of the new process is, as A. Trappen * points out, to avoid intermediate cutting into lengths, partly because their manufacture entails considerable cost, and partly because a sheet is produced which has sides more or less crumpled and torn, necessitating their removal, and consequently inducing a great waste of material. The author was intrusted with the elaboration of Wittgenstein's idea, and he describes the arrangement finally introduced.

The ingots, which are $15\frac{3}{4}$ inches broad, $11\frac{13}{16}$ inches thick, and $23\frac{3}{8}$ inches long, are first rolled in a universal mill with steel rolls $23\frac{3}{4}$ inches in diameter, down to plates 2 inches in thickness. They are then run by a truck to shears, after which they are reheated. The plate is then cleaned from scale, and is passed through a Lauth three-high mill, where it is rolled to $\frac{5}{16}$-inch in thickness. This mill and the universal mill are both driven by the same engine, which is connected to one or the other by clutches. The table of the three-high mill is worked by hydraulic power, and at the last pass delivers the plate on to live rollers, which carry it to a series of five two-high mills placed one behind the other. These mills are driven at a high speed by a larger engine, and reduce the

* *Stahl und Eisen*, vol. xii. pp. 999–1000, with plate; *Industries*, vol. xiii. pp. 550-552

plate to a sheet about $\frac{1}{16}$-inch thick, 150 to 160 feet long, and about $3\frac{1}{4}$ feet broad. The sheet is taken up by live rolls and sheared into three lengths, which can afterwards be treated as desired, and is sold as a finished product. The rolls of the two and three-high mills are $24\frac{13}{16}$ inches in diameter, and are all adjusted mechanically. The two-high mills only require one attendant, but the men at the three-high mill accompany the plate as it passes through the succeeding rolls. About 30 tons daily are turned out, but the capacity is greater than this.

New Rolling-Mill.—A description is given by Mr. Jeremiah Head,* of a 28-inch steel mill, with shears and subsidiary plant, for the New British Iron Company, Birmingham. The cogging and shearing plant is designed to deal with ingots weighing not more than 20 cwts., and 15 inches square at the thick end. These are to be rolled into billets ranging from 6 to 3 inches square, or from 7 by 3 to 6 by 2 inches. The bed-plate had to be of sufficient length to allow of the addition of a finishing-train. The shears are to cut up to 10 inches square, or 20 by 5 inches, at six strokes per minute. The boiler-pressure is 100 lbs., and accumulator-pressure 700 lbs. per square inch. Horizontal non-condensing reversing engines are employed, with two cylinders 36 inches in diameter by 42-inch stroke. Piston-valves and very large steam-pipes are used. Each crank with its balance-weight and crank-pin forms one steel casting. Other details, with an account of the Hackworth or Marshall valve-gear, are given. Helical gear, with bevel-ended teeth instead of shrouds, is used, and the ends of the second motion-shaft are shaped to the form of the wobbler-ends of the rolls.

The cogging-mill rests on a deep girder, the housings being bolted to it so that they can be adjusted to receive any length of rolls. The movement of the top roll is 15 inches, and it is adjusted by a small engine. One feeding-roller on each side is carried in the housings, and is driven by a chain from the live rollers. The main rolls are 8 feet long in the barrel, and 28 inches in diameter. The necks are 18 inches long and 18 inches in diameter. Between the train and the hot bloom shears, a description of which is also given, are live rollers, and a swing frame is fixed on the delivery side of the shears.

Gauging Plates during Rolling.—Mr. R. B. Haines† describes an automatic micrometer gauge for gauging either hot or cold rolling

* Paper read before the Cleveland Institution of Engineers, February 20, 1893; *Engineer*, vol. lxxv. p. 237, with double plate.

† *Journal of the Franklin Institute*, vol. cxxv. pp. 42–45.

work to exact thickness while in the act of rolling. The jaws of the gauge are set so as to pass easily over the work, and then by a trigger release a gauge screw is turned by a spiral spring so as to come up to the plate. The screw is then locked by another trigger device and catch, after which the gauge is pulled off the plate and the graduations on the screw-head are read. The gauge weighs about 2¼ lbs., and can be worked by one hand. It will replace a large number of the ordinary fixed callipers. This device has been in successful use for some months.

New American Rolling-Mills.—A rolling-mill recently erected at Peoria, Illinois, comprises four trains of rolls, one of which is an 18-inch train, one a 10-inch, and two of 8-inches. The plant also includes two heating-furnaces fed by oil, and one fed by producer gas. One 30 by 30-inch Corliss engine drives the two 8-inch trains, and another 32 by 36 inches, the 18-inch and 10-inch ones. Steam is supplied by fourteen boilers.*

A form of mill, designed by Mr. C. W. Bray of Ohio, is intended for rolling sheets or plates from sheet-bars or slabs, and several mills of this type have been erected at some of the larger United States steel-works. The mill is so arranged that the roughing rolls are connected directly to the finishing rolls, thus doing away with the set of pinions usually employed at one side of the set of balanced roughing rolls and connected with them. The upper roughing roll is driven from the frictionally-driven uppermost finishing roll. Other details relating to the arrangement of this form of mill are also given.†

The Pacific Rolling Mill is situated at San Francisco. It contains a train of rolls large enough to roll a 20-inch steel slab I beam, the first set of housings being used as a blooming-mill, and two sets as roughing and finishing rolls. Full drawings are published ‡ of the Corliss engine that has been erected for this mill.

The Failure of Chilled Rolls.—Mr. B. H. Thwaite § discusses at some length the failure of chilled rolls, and offers several theories as to the causes, chiefly based on the thermal influences. In the ordinary casting process, the metal is cast in a chill, and the skin at once solidifies, leaving a fluid centre which sets more gradually. The shrinkage of the

* *Iron Age*, vol. l. p. 569.

† *Ibid.*, vol. li. p. 557, with two illustrations.

‡ *Ibid.*, pp. 620–623, with eight illustrations.

§ Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, December 10, 1892.

centre on solidification leaves a cavity which is kept filled from the gates. On this account the gates should have sufficient head, and should be maintained at a high temperature. The escape of gases is referred to, and also the resistance of the metal being rolled at various temperatures. The failure of rolls may be ascribed to several causes. Of these, the first is faulty design, the rolls having necks too small or without sufficient gradation in size from the body of the roll. Imperfect castings, excentrically turned rolls, or accidental strains from the passage of a tool, may also be causes of failure. As for the quality of metal used, sulphur should not be high, since it reduces the strength at elevated temperatures, though for cold rolling it is not of great importance. The action of silicon is not well understood, but probably it acts like hardening carbon. Manganese and carbon are the only elements that are to be regarded as beneficial.

A summary of the discussion on Mr. C. A. Winder's paper * on the failure of the necks of rolls is given. The varied distribution of the carbon and other elements in the castings both in the chill and elsewhere is a field for investigation. The strains set up in the casting by the cooling of the metal are discussed, the difference of volume on contraction both in the neck and in the body of the roll being calculated. The different speeds of cooling of these two parts is a further cause of strain. Attention is then directed to the phenomena associated with the fall of temperature from the fluid to the solid condition. Some notes from Mr. Reimer's paper † on the manufacture and application of chilled cast iron on Gruson's system are given as bearing on this subject, and the following is given as a typical analysis of a good metal to use :—

Carbon Combined.	Carbon Graphitic.	Phosphorus.	Silicon.	Sulphur.	Manganese.
0·635	2·865	0·25	0·65	0·05	1·50

The metal should be melted in a reverberatory furnace, and raised to steel melting-heat before pouring. The roll is to be cast in two parts separately, an outer chilled part and an inner part, with a central passage for water. The inner part is to be cast in a hot mould, and has ribs on it which support the chilled casing which is fitted on. Strains set up by cooling the interior of the rolls when rolling hot metal are then considered. A lengthy discussion ensued in which the opinions of the author were severely criticised.

Mr. E. J. Duff ‡ has investigated the strains to which rolls are sub-

* *Journal of the Iron and Steel Institute*, 1892, No. II., p. 176.

† *Ibid.*, No. I., p. 126.

‡ Paper read before the West of Scotland Iron and Steel Institute, January 17, 1893.

jected and the means available for strengthening cast iron rolls. Some experimental rolls have been at work, in which a number of wrought steel bars are cast into the barrels near the outer circumference. Numerous illustrations are given.

Rolling-Mill Engines.—Drawings of a pair of high-pressure, non-condensing, reversing mill engines for the Melyn Tin-plate Works have been published.* The engines have cylinders 40 inches in diameter, and the stroke is 4½ feet. Joy's valve gear is used.

The new engines for the universal slabbing-mill of the Pennsylvania Steel Company consist of a pair of 42 by 60 inch reversing engines geared to drive the horizontal rolls, and a pair of 26 by 30 inch reversing engines, directly connected to the driving shaft of the vertical rolls. The gears are of steel, 36-inch face inside of shrouding, 8-inch pitch, and are 4 feet and 10 feet pitch diameter. These engines are all rigidly connected on a continuous bed, and occupy a space 63 feet long. They weigh 300 tons.†

Steam-Hammers.—Several illustrations of steam-hammers have recently been published.‡ One of these is a small hammer with A standards, and the other is a ten-ton hammer with a bow frame without slides, which gives plenty of room for the manipulation of heavy and intricate forgings.

Steam Forging-Press.—An illustration has been given§ of a forging-press in which steam is used instead of hydraulic power. With steam at 60 lbs., the press can exert a pressure of 100 tons. There are two cylinders, superimposed, the piston-rod of the lower working through the upper piston.

* *The Engineer*, vol. lxxiv. pp. 482, 490.
† *Iron Age*, vol. li. p. 568.
‡ *Iron*, vol. xl. p. 443, vol. xli. pp. 69-70.
§ *Ibid.*, vol. xli. pp. 288-289.

PRODUCTION OF STEEL.

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I.—*THE CARBURISATION OF MALLEABLE IRON.*

Austrian Crucible Steel.—Dr. E. Prziwoznik * gives the following results of analyses of crucible steel:—

	1.	2.	3.	4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Combined carbon	0·83	1·062	2·072	1·780
Silicon	0·08	0·187	0·700	0·560
Phosphorus	0·03	0·016	0·030	0·038
Sulphur	0·02	0·013	0·011	0·024
Manganese	0·31	0·160	1·539	0·760
Copper	0·04	0·010	0·010	trace
Chromium	2·50	...	...	1·340
Tungsten	...	0·447	6·140	...
Iron	96·18	98·105	89·498	95·498

Crucible steel (1) from the Austrian Alpine Company, (2) from Böhler Brothers in Vienna, (3) tungsten steel from Kapfenberg, and (4) chromium steel from the Austrian Alpine Company.

II.—*THE OPEN-HEARTH PROCESS.*

Mild Open-Hearth Steel for Castings.—Messrs. A. B. Winder and J. D. Brunton † give a full description of a heat made in a small acid-lined open-hearth furnace at the Sheffield Technical School.

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 471–473.

† Paper read before the Sheffield Technical School Metallurgical Society; *Iron*, vol. xli. pp. 334–335.

The furnace was charged at 5.55 P.M. with 240 lbs. chrome scrap, containing 1 per cent. of chromium; 344 lbs. of scrap; 220 lbs. of chrome pig iron, containing 5 per cent. of chromium and 3 per cent. of silicon; and 791 lbs. of Millom hæmatite pig iron. The composition of this pig iron and the initial composition of the charge were as follows:—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.	Chromium.
3·83	1·2	0·5	0·04	0·045	...
2·83	1·0	0·5	0·05	0·070	1·0

The charge took 110 minutes to melt, and was tapped at 12.20. Ore was added in three lots of 56 lbs. each, at 7.50, 8.50, and 11.5 P.M. Ferromanganese was added at 12.5 and 12 oz. of aluminium was placed in the ladle before tapping.

The composition of the red hæmatite ore used was as follows:—

Fe_2O_3.	MnO_2.	Al_2O_3.	CaO.	MgO.	SiO_2.	P_2O_5.	SO_3.
81·5	none	0·84	0·93	0·11	16·12	0·042	0·2

And the ferromanganese had the composition—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.	Iron.
6·8	1·1	77·7	0·01	0·3	14·0

Samples of the bath were taken at the times indicated in the table below, which shows their composition—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Initial Charge.	Finished Metal.
	P. ct	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
C . . .	1·90	0·78	0·64	0·47	0·28	0·21	0.15	0·13	2·83	0·30
Si . . .	0·40	0·26	0·04	0·06	0·03	0·1	0.15	0·02	1·00	0·10
Mn . . .	0·30	0·03	0·02			Trace			0·50	0·53
Cr . . .	0·68	0·6	0·50	0·44	0·39	0·34	0·29	0·21	1·00	0·19
Time . .	7.45	8.15	8.45	9.15	9.45	10.15	10.45	11.15	...	...

The furnace was fired with producer gas, analyses of which at various stages are given. The tensile strength of the metal on a two-inch test piece of about half an inch in diameter showed as follows:—

	Tensile Strength.	Elongation.	Reduction of Area.
	Tons per Sq. Inch.	Per Cent.	Per Cent.
Unannealed . . .	31·5	13	13·8
Annealed . . .	32·71	15	22·5

A bar $\frac{7}{8}$-inch square was bent to an angle of 50°, at which it broke.

Water-Cooled Doors for Open-Hearths.—B. Zsokke* observes that the opening closed by the working and charging doors of open-hearth furnaces are usually surrounded by cast iron or steel plates protected by fire-resisting material. Between the door and the opening it closes, there is usually a flame playing out, and this corrodes and melts away this metal casing. At the open-hearth furnaces of the Witkowitz steel-works the air for the combustion is blown under more than ordinary pressure, and it was found that with the ordinary plate-casings for the door-openings the wear is very considerable after as short a time as a few weeks. That portion of the furnace arch which is immediately above the doors is also exposed to very considerable wear, owing to the flame which plays out through the doorway. It has, therefore, to be frequently repaired, which leads not only to the extra expense of the actual repairs, but frequently also to slight disturbances of the actual work. The red-hot metal around the doors has also the disadvantage of being extremely trying to those workmen who, during the charging of the furnace, have to approach close to the working door. To avoid all these difficulties, experiments were made which finally led to the adoption of bronze water-cooled castings in the place of the ordinary plates. These, though costly in the first instance, do not crack, and wear but little. The doors, too, were also made of water-cooled bronze castings, and both these improvements, though costly in themselves, have led to a considerable saving in working expenses.

The Open-Hearth Process.—W. Soltz† publishes a critical examination of the open-hearth process, and of the furnace employed. After referring to the chemical and mechanical characters of the various kinds of ingot-iron, he proceeds to discuss the open-hearth furnace. Placing the regenerators below the furnace, while possessing the advantage of protecting them from cooling influences, has the disadvantage of rendering repairs a matter of difficulty. The walls of the regenerators, too, having to support the weight of the furnace, must be made very thick, and the surrounding soil must be carefully drained. These were the causes which led to the regenerator being built separate from the furnace. They were still erected horizontally, however, an arrangement which is not the most perfect for a complete utilisation of the whole surface of the brickwork contained in the chamber. Recently these horizontal chambers have begun to be replaced by vertical

* *Stahl und Eisen*, vol. xiii. pp. 184–186, with two illustrations.
† *Magyar bányászati és kohászati irodalom pártoló egyesület.*

ones, after the type of the Cowper stove, and these are placed in a similar way at the sides of the furnace. This arrangement was first introduced in England. It is now employed at a number of Continental works, as, for instance, at the Phœnix Works on the Ruhr. The weight of these regenerators being taken up by columns, the bottom is quite free. The smaller regenerators are the less capable of retaining heat, and the direction of the incoming gases requires to be changed at very frequent intervals in order to prevent the furnace being subjected to changes of temperature. The sectional area of the regenerators must vary with the quantity and character of the fuel consumed. In general, for every connected pair of regenerators it is customary to give a sectional area of from 2·5 to 3 square metres for every 100 kilogrammes of coal burnt, and from 1·5 to 2 square metres for the same quantity of brown coal. For every kilogramme of coal burnt per hour the capacity of such a pair of regenerator chambers would be from 0·04 to 0·07 cubic metre, Gruner having estimated it at 60 kilogrammes of bricks, or approximately 0·033 cubic metre, calculating the specific gravity of the bricks at 1·8. The vertical regenerators are rarely built to a greater height above the channels below them than 8 or 10 feet. The author gives various examples illustrating the size of regenerator chamber. At an Austrian works the vertical gas and air regenerators are each of 16·4 cubic metres capacity, serving a twelve-ton furnace. At a German works an eight-ton furnace is served by gas-regenerators of 8·56 cubic metres capacity, and air-regenerators having a capacity of 12·48 cubic metres. The size of the working-hearth must depend on the intended out-turn of the furnace, and its dimensions are also in part determined by the chemical composition of the pig-iron to be treated, the shallower the bath the greater being the surface of the metal exposed to oxidation. Under ordinary circumstances the depth of metal should not exceed about 8 inches, and only in basic-lined furnaces does the depth reach to as much as 20 inches, owing, in this case, to the large quantity of slag that is produced. The bed of the furnace is always formed of iron plates, and the length of the hearth is half as much again as its width. The author next proceeds to give details as to the usual size of the hearth, the following being considered typical:—

Capacity of furnace, tons . . .	7	8	10	12
Surface of the hearth, square metres.	8	10	12	14
Length, metres	4·2	4·4	5·0	5·4
Breadth, metres	1·9	2·4	2·5	2·6

the limits being about as follows:—

Capacity, tons . . .	7	8	10
Surface, square metres . .	7·0 to 8·3	9·8 to 10·4	9·2 to 12·5
Length, metres . . .	3·2 to 4·2	...	3·8 to 5·0
Breadth, metres . . .	1·9 to 2·3	...	2·3 to 2·7

The larger the furnace the greater difficulty appears to be experienced in eliminating the phosphorus present in the bath, the reason for this lying in the fact that the roofs even of basic-lined furnaces are of acid material, and the larger the roof surface that is exposed to the action of the high temperature existing in the furnace, the greater will be the amount of silica which is melted off and which passes into the bath of slag. The position of the gas and air ports must be so chosen that as little slag is carried into them as is possible. They must therefore be placed at an adequate height above the bath. They must also be arranged in such a manner as to cause as intimate a mixture as possible between the air and the gas. Sometimes there are only three of these ports, placed in a line, the central one being used for gas and the others for air. On the other hand, the author mentions a furnace in which there were nine such ports in a line, four being used for gas and five for air. This side-by-side arrangement is not so well suited for completing the combustion of the gas as are those in which the air ports are above those through which the gas escapes. The specific gravity of the gas being less than that of the air, it rises through it, and an intimate mixture is in this manner obtainable. The total sectional area of the gas ports (*a*) is so chosen as to equal on each side three-fourths of the area of the grate-surface of the producers, the air ports being either of the same size or, in some cases, only half as large. The author, after considering the other details of the furnace construction, then passes in review the various basic materials that have been employed as basic linings, and the components of the furnace charge. Both the acid and the basic processes are considered, as well as the use of the usual deoxidising materials, and of aluminium. The use of fluorspar in rendering basic slag thin fluid is also referred to, and the actual smelting process itself is also considered, the mode of elimination of the various impurities being shown by means of a table giving analyses both of the bath of metal and of the slag at various periods of a charge. In a similar table details are given of the working off of a pig iron and ore charge in a basic-lined 8-ton furnace.

The Schönwälder Open-Hearth Furnace. — An account has already been given * of the results obtained in the working of the

* *Journal of the Iron and Steel Institute*, 1892, No. II., p. 453.

Schönwälder open-hearth at the Friedenshütte, Upper Silesia. Further details respecting the furnace and its working are published by H. Dowerg,* the manager of that works. He refers to the various improvements which have been introduced in this furnace, and to the great improvement in the working results which these have brought about, the wear and tear of the furnace being very greatly diminished. The chief modification consists in the use of a number of regenerative chambers in place of the smaller number commonly employed, one for each opening at the upper part of the furnace, each such chamber having its own separate flues leading to the reversing valves, and each such channel being provided with a separate valve, which enables the regenerator to be thrown completely out of use if the wear of the furnace becomes extreme at the point affected by the gases from such regenerator. The description is aided by a number of illustrations showing the arrangements adopted. The arrangement of the flues was far from being a matter of minor importance, and that finally adopted is described by the author. The furnace as now constructed has shown remarkable endurance. The metal made has had the following composition :—

No. of Heats.	Percentage of Phosphorus.	No. of Heats.	Percentage of Carbon.
532	Under 0·05	594	Under 0·1
162	0·05 to 0·08	103	0·1 to 0·2
18	Over 0·08	15	0·2 to 0·5

After the completion of this campaign the repairs necessary proved comparatively slight, and the furnace was in active operation again after a fortnight's interval.

The same Schönwälder open-hearth has, since the above-mentioned, 712 charges, made another 512 charges † down to February 16, 1893, producing 6598 tons of ingots. After the 365th charge repairs to the roof had to be effected, which required three days to complete. The average number of charges put through in the working day was 3·31, yielding 41·2 tons of ingots. The metal produced was mostly soft, only a small portion for special purposes being made hard. Analysis showed the metal from 435 charges to contain less than 0·1 per cent. of carbon, that from 69 charges from 0·1 to 0·2 per cent. of carbon, while in only 5 charges did the iron contain more than 0·2 per cent. of carbon. The percentage of phosphorus was less than 0·05 per cent. in the ingot metal

* *Stahl und Eisen*, vol. xii. pp. 989–996, nine illustrations.
† *Ibid.*, vol. xiii. p. 258.

resulting from 335 charges, and from 0·05 to 0·08 in a further 188 charges, while it exceeded 0·08 in only 7.

Tilting Open-Hearth Furnace.—Drawings of a tilting open-hearth furnace are published in the *Iron Age*.* Two such furnaces, each of 15 tons capacity, have been in use for more than two years at the works of the Pennsylvania Steel Company. The furnace is provided with rocker bars resting on a series of anti-friction rollers set between the lateral confining plates of curved rails. The tipping of the furnace is effected by the aid of a hydraulic cylinder provided with a cross-head, and connected by links with the rocker frame of the furnace.

Early Open-Hearth Steel Manufacture.—Some of the early struggles of open-hearth steel-making and of steel-casting manufacture are described by Mr. W. Shaw.† Together with Mr. C. Attwood, the author began to experiment in 1858 on melting together wrought and cast iron, and near the end of 1863 some cast steel projectiles were made under a patent taken out by the former. Although untempered, these projectiles met with great success. At this time Mr. Siemens was bringing out his regenerative furnace. One was built, but proved a failure, and it was accordingly turned into a crucible furnace. This succeeded very well, but as the Palliser chilled cast-iron shells were being introduced, attention was successfully directed to the production of billets for the manufacture of wire rope. In 1865 they again reverted to a form of the open-hearth furnace fired with producer gas. After some attempts some rails were produced, and were found to wear well. The question of price, however, caused them to keep to the wire-rope steel, and to undertake the manufacture of cast-steel wheels, which were soon found to be of great value. Dredger buckets also occupied their attention, and an account of the introduction of these is given.

The question of the regulation of the heat in the furnace has been fairly well solved, but there is still a good deal to be done with the moulding material, as the carbon paint is likely to alter the carbon in the steel. The question of the design of castings is also considered.

The Utilisation of Heat in Regenerative Furnaces.—E. Damour‡ describes the new form§ of Siemens furnace arranged to

* Vol. l. p. 668, two illustrations.

† Paper read before the Cleveland Institute of Engineers, January 16, 1893.

‡ *Annales des Mines*, ninth series, vol. iii. pp. 84–129.

§ *Journal of the Iron and Steel Institute*, 1889, No. II., p. 256.

utilise waste gases as well as waste heat. From a detailed theoretical study based on experimental researches with two Siemens furnaces, the author believes that there is considerable economy in favour of the new form.

The Stanners Closes Steelworks.—The Stanners Closes Steelworks at Wolsingham were founded in 1864 by Mr. C. Attwood.* The works chiefly produce steel castings and forgings, and cover about 20 acres of ground. The melting shop contains five regenerative melting furnaces of 8, 4, 4, 3, and 2 tons capacity respectively, and two pot furnaces. The charges consist of steel scrap with about 5 per cent. of pig iron made from Gellivara ores with silicon spiegeleisen or ferro-manganese. An account is also given of the other parts of the works and of the gas producers.

The Works of the Carbon Steel Company.—Drawings are published† of the works of the Carbon Iron Company, Pittsburgh, Pennsylvania. The works cover 8 acres of ground in the centre of the city, and owing to the high valuation of the land the utmost use has to be made of it. New works have therefore been erected. The plant includes six open-hearth furnaces, of 30 tons capacity, and two of 15 tons. They are all of the Lash type, having the regenerators in the flue leading to the stack, and at present are all worked with natural gas. There are four soaking pits, or pit furnaces, with holes of unusual size, in connection with a plate and universal mill. In addition to these there are four large heating furnaces used exclusively for blooms and slabs. The soaking-pits, &c., are served by two 10-ton electric cranes, which travel at high speed. In the plate mill the screws are driven by an electric motor. The cooling tables are 375 feet in length from the centre of the mill to the blade of the shear. The rollers are 13 inches in diameter, 6 feet in length, and spaced 2 feet 7 inches between centres. The main shear has a blade of 137 inches, and it is capable of cutting metal up to $2\frac{1}{2}$ inches thick. A duplicate shear, weighing 185 tons, is in course of erection. The plate mill has three-high rolls, 34 by 124 inches, the middle roll being of the dimensions 20 by 124 inches. There are lifting tables on either side, each having a capacity of 10 tons. The pinions are of steel, and each roll housing weighs 26 tons. The plant includes in addition to this a 124-inch three-high plate mill, a 36-inch universal mill, and a 48-inch sheet mill.

* *The Engineer*, vol. lxxv. pp. 201–202, with illustrations.
† *Iron Age*, vol. li. p. 560, with detailed plan of works.

The Manufacture of Steel in the Southern United States.—A Committee appointed to consider the question of the possibility of the profitable manufacture of steel in the Birmingham district have published their report.* They commenced by a consideration of the various possible processes for the manufacture of steel, pointing out that the great difficulty in the case of the acid Bessemer and open-hearth processes was that the pig iron to be used should not contain more than 0·1 per cent. of phosphorus. In the basic Bessemer process, too, only specially suitable metal can be employed, the pig iron being required to contain from 2 to 2½ per cent. of phosphorus. On the other hand, the basic open-hearth process admits of a much wider range as regards the materials that can be employed, the only absolutely important restrictions in the case of the pig iron being that it shall be low both in silicon and in sulphur.

The report refers more directly to the possibility of the manufacture of steel by the Tennessee Coal, Iron, and Railroad Company, and the committee point out that in view of the character of the pig iron made at the various blast-furnaces belonging to that Company, the acid processes are impossible. In the case of the basic Bessemer process, too, while a pig iron containing the necessary amount of phosphorus might be made, the ores of the Red Mountain district that are at present smelted would have to be replaced by the brown iron ores of Georgia and Alabama. The Committee next considered the possible use of the basic open-hearth process. They pointed out that all the higher grades of Southern coke pig iron are low in sulphur, and the question of the silicon raises the only important difficulty. It is customary in basic open-hearth working to add from 25 to 50 per cent. of scrap to reduce the percentages of silicon and of carbon in the bath, but at present it is not possible to obtain scrap in sufficient quantity in the Birmingham district referred to in this report. White and mottled iron can, it is true, be used with a relatively small percentage of scrap, but in ordinary Southern furnace practice this would be followed by such an increase in the percentage of the sulphur present as to greatly impair the value of the steel made.

Southern grey pig iron usually contains about 0·75 per cent. of phosphorus, 0·01 to 0·04 of sulphur, and 1·50 to 2·25 of silicon. To eliminate the silicon the Committee suggest that the molten pig iron should be run through a bath of basic slag as in the Talbot process.

The question of the establishment of a plant was next considered from the point of view of commercial success. To ensure this, the plant, the

* *Iron Age*, vol. li. p. 669.

Committee observe, should be a large one, with a minimum capacity of 500 tons a day. The cost of erection would be about £200,000.

Casting Ingots.—L. Sebenius,* manager of the Nykroppa Ironworks, Sweden, casts steel into ingot moulds which are pivoted on swinging arms. These arms are then rotated at the rate of 125 revolutions per minute. Centrifugal action causes the ingot moulds, with their steel contents, to assume a horizontal position. In this way the metal is subjected to a certain degree of compression, and sound ingots are said to result.

Mr. F. Korb† describes the properties and mode of production of sound steel ingots and castings.

Ingot Moulds.—Illustrations are given‡ of the hydraulic ingot-moulding machine devised by Mr. J. B. D. A. Boulton, which has been in successful use for some four years at Sheffield. This machine will produce 144 ingots, weighing 85 lbs., per day, free from piping. The ingots are cast with a head of 4 or 5 feet, which is then sheared off to the proper length. Hydraulic cylinders are used to raise and lower the ingot mould, which is bottomless, and to shear off the ingot. The waste is stated not to exceed 3 per cent. Ingots from 3 to 3¾ inches square and from 18 to 25 inches long are made at Sheffield, and larger machines are in use in the United States.

Mr. J. Riley§ describes a form of ingot mould which has been devised to obviate the difficulties due to the top being smaller than the bottom, as is the general practice. In the usual form, the smaller upper end, which is unsound, does not get so much work put into it as the larger end, where it is not necessary. The crane power required for stripping and other operations in the casting pit is large, and may well be reduced. Moulds with trunnions, so that they can easily be reversed, have been used and abandoned, but no detailed particulars as to their use are available. Mr. Dick proposed that loops should be suspended across the top of inverted moulds and used for withdrawing the ingots, but unfortunately not enough time could be allowed for sufficient cooling, so the crane hook often dragged the loop out of the ingot. This difficulty was

* *Stahl und Eisen*, vol. xiii. pp. 152–154, four illustrations.

† Paper read before the London Association of Foremen Engineers and Draughtsmen, November 5, 1892.

‡ *Industries*, vol. xiv. p. 156.

§ Paper read before the West of Scotland Iron and Steel Institute, February 17, 1893.

overcome by casting the mould with openings to admit the dogs, these openings being filled with key or wedge pieces during casting. These wedges are an easy fit, and can readily be removed after the metal has solidified. The mould stands on a curved surface, so that the cogged slab made from the ingot has a square end.

Steel Casting Ladle.—An illustration of a steel casting ladle made by a Preston Company has been given.* The design is adapted for sizes to hold from 10 to 40 tons. The shell is of $\frac{3}{4}$-inch steel plates, welded at the vertical joints with a riveted-in flanged bottom. The shell and bottom are perforated with $\frac{5}{8}$-inch holes for adhesion and ventilation of the ganister lining. A simple tapping gear with direct lift is used, and is carried by a plate bracket, which is readily detachable. The cast-iron nozzle box is hinged so that the lining may easily be replaced. Four ears for lifting are provided. The ladle is mounted on trunnions on a trolley, and has worm tilting gear.

III.—*THE BESSEMER PROCESS.*

German and Austrian Bessemer Blowing Engines.—The statistics relating to the construction and working of the blowing engines used in Rhineland-Westphalia, Upper Silesia, and Austria-Hungary, collected by A. von Ihering,† and abstracted in the section of this volume dealing with blast-furnace practice, include particulars of the blowing engines used at Bessemer steelworks. The distribution of these engines is as follows :—

Country.	No. of Works.	No. of Engines.
1. Rhineland-Westphalia . .	10	17
2. Austria-Hungary . . .	12	17
3. Upper Silesia	2	2
Totals . .	24	36

* *Industries*, vol. xiii. p. 621.

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 381–452.

Classified according to their construction the engines are as follows:—

Country.	No. of Works.	No. of Engines.
A. *Vertical Engines.*		
1. Rhineland-Westphalia . .	3	4
B. *Horizontal Engines.*		
1. Rhineland-Westphalia . .	8	13
2. Austria-Hungary . . .	12	17
3. Upper Silesia	2	2

From these figures the following rough generalisations may be drawn:—For Bessemer works the horizontal blowing engines are everywhere preferred to vertical ones, the preference being easily explained by the greater stability required for the great number of revolutions. Beam engines are not used at all, and vertical blowing engines are used only in Rhineland-Westphalia to the extent of some 10 per cent. of the total number. The number of Bessemer steelworks and of blowing engines is practically the same in Rhineland-Westphalia and in Austria-Hungary. The details given in the fifty pages of statistics are the same as those given in the case of the blast-furnace blowing engines.

The Tudhoe Steelworks.—An illustrated account of the Tudhoe iron and steel works at Spennymoor has recently been given.* At these works the Bessemer process was first worked. The steel melting house contains seven acid-lined open-hearth furnaces in line, five of which are of 20 tons capacity, and two of 16 tons. Their charge consists of 25 per cent. of steel scrap, 15 per cent. of ore, and 60 per cent. of pig iron made by the works from Spanish ore. Particulars are given of the gas producers, and of the reheating and soaking furnaces. The cogging and rolling mills are also described, and some details are given of the blast-furnaces.

The Vizcaya Ironworks, Bilbao.—During 1892 three Robert converters were put into activity at these works. The nominal capacity of 2½ tons has been increased in actual practice to 4½ tons. The number of these converters is to be increased to five, thus raising the capacity of this works to about 80 or 100 tons of steel in the day of

* *The Engineer*, vol. lxxv. pp. 331-334.

twelve hours. When the plant still in course of erection is completed, this works will possess:—Four open-hearths with a daily capacity of 75 tons; the five Robert converters already referred to; four heating furnaces and one double furnace, with a total daily capacity of 20 tons. There are also six trains of rolls of various sizes. In 1892 this works produced 102,818 tons of pig iron, 15,882 tons of open-hearth steel, 6648 of Robert steel, 4371 of puddled iron, and 22,084 tons of rolled products, 89,905 tons of coke and 152,059 of iron ore being used in the furnaces.*

The Manufacture of Steel by the Basic Process.—F. Tordeur † describes a method of renewing the linings of the basic Bessemer converter, the method being to a certain extent a modification of that proposed by Holley, in which the converter is moved bodily. It is intended to make the linings in three parts—the mouth and upper part, the body, and the bottom. These parts are carried and put into place by a hydraulic cylinder mounted on a truck, and the parts of the lining are supported in the shell of the vessel by a system of brackets and iron rings. The various materials used for the lining are mentioned, and an account of their preparation is given. The pig iron used should preferably contain less than 1 per cent. of silicon, but if the percentage falls below 0·7 it is necessary to use good coke in the fusion to get a hot metal, or to raise the manganese over 2 per cent., so that heat enough is obtained in the first blow to render the bath thoroughly liquid. Desulphurisation with the aid of manganese is mentioned. Phosphorus varies from 1·80 to 2·40, but if it is too low more silicon must be present, and if it is over that limit the blow is very hot, and in both cases much time is required. Manganese should preferably be present to the extent of 1·75 per cent., and graphitic carbon should be abundant. The author then discusses at some length the number of workmen employed and their wages, both in France and in Belgium, and also gives an estimate of the cost of production at Charleroi, Liége, Dudelange, and Longwy.

With coal at 8 francs the ton on waggons at the collieries, and with coke at 14 francs the ton at Bracquegnies, Belgium, the author estimates the cost of making a ton of ingots at Charleroi to be as follows:—

* *Revista Minera*, vol. xliv. p. 125.

† *Revue Universelle des Mines*, vol. xx. pp. 1-26.

	Francs.
Waste of pig iron, 330 to 440 lbs. per ton	10·51
Coal, 330 to 364 lbs.	1·40
Coke, 88 to 99 lbs.	1·72
Dolomite, 121 to 132 lbs.	0·30
Lime, 396 to 419 lbs.	1·62
Coal tar, 11 to 13 lbs.	0·42
Refractory materials	0·85
Ingots, moulds and bases	0·95
Plumbago	0·35
Miscellaneous expenses and repairs	1·40
Handling waggons and switching	0·10
Wages	2·09
General expenses	0·50
Sinking fund	0·50
Ferro-manganese, 11 to 13 lbs.	1·50
Total	23·12
Deduct value of slag	3·00
Net cost of converting	20·12
Add cost of pig iron	52·55
Total cost	72·67

The total cost of the ton of ingots at Dudelange is estimated by F. Tordeur at 63·53 francs, and at Longwy at 67·79 francs. The author, in making these estimates, starts with the assumption that a plant of three 10-ton converters, taking metal direct from a blast-furnace plant, could produce 150 tons of ingots in twenty-four hours. The question of the cost of labour is considered in much detail.

C. Palgen * and F. Tordeur † state that the older Basic bessemer steel-works in Belgium, such as the Angleur Works, had two converters placed opposite one another, and served by a central crane. To obtain an equal outturn as compared with that of the acid process, two such plants were necessary, so that of four converters only one was in constant work. A more economical arrangement consisted in the use of a single pit, with three converters placed in a semicircle around a central crane. This arrangement has been adopted at the Mont-Saint-Martin Works. Such an arrangement can be used with success up to a daily outturn of 250 tons of ingots, but with a greater output than this the American method should be employed, the converters being arranged in pairs around a central crane. This method of arrangement has been employed at the basic Bessemer works at Hayingen, Joeuf, and Dudelange. At Hayingen there are now six converters placed in a straight line, and these

* *Mémoires de l'Union des Ingénieurs de Louvain*, 1892.

† *Stahl und Eisen*, vol. xiii. pp. 101-111, six illustrations.

are served by three central cranes. To empty the moulds seven other cranes are employed. There are two cupolas for the remelting of pig iron, and two spiegeleisen cupolas, but these are now rarely employed, the iron being taken direct from the blast-furnace, and the decarburised metal being recarburised by the direct carbon process. The remelting cupolas are 21 feet 6 inches in height, 55 inches wide at the tuyeres, and 67 inches wide in the shaft. They are blown through eight tuyeres, take a charge of from 7 to 8 tons of pig iron, and melt this at a cost of 11 per cent. of coke and 2·3 per cent. of limestone. Each cupola is served at the top by two chargers, and below by a smelter and four workmen. There is a considerable loss in remelting both of silicon and of manganese, analysis having shown the following :—

Description.	Charge 1961.		Charge 1962.		Charge 2038.	
	Before Melting.	After Melting.	Before Melting.	After Melting.	Before Melting.	After Melting.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silicon	1·089	0·738	1·083	0·653	1·602	1·337
Manganese . . .	1·947	1·478	1·083	1·334	2·028	1·592
Phosphorus . . .	...	...	...	...	2·535	2·646

The average loss of silicon on remelting was therefore 0·349, and of manganese 0·455, whilst the percentage of phosphorus remains almost unchanged. In a charge in which 11·6 per cent. of coke was used as well as 2·5 per cent. of limestone for flux, the cupola slag had the following composition :—

SiO_2.	Al_2O_3.	FeO.	MnO.	CaO.	MgO.	P_2O_5.	S.
38·90	4·70	4·40	8·93	37·80	2·80	1·20	0·53

The converters at the Hayingen Works are of only 7 tons capacity, whilst the Joeuf converters take a 10-ton charge. A mixture of ground fritted dolomite and anhydrous tar is used for lining the converter body and for forming the bottom. The throats of the converters are lined with dolomite bricks, except the last few upper courses, which are of ordinary acid firebrick. At the Creusot Works, limestone obtained from Mazenay, in the Department of the Saône and Loire, when burnt and fritted, is used for lining the converters. Analysis shows it to contain—

SiO_2.	FeO.	Al_2O_3.	CaO.	MgO.	CO_2+H_2O.
2·4	2·4	1·7	54·0	0·5	41·2

These bottoms usually last about 25 charges, though they have withstood up to 50 charges, while the lining of the converter body lasts about 150 or 160 charges. At present nearly the whole of the larger basic Bessemer works use metal taken direct from the blast-furnaces. By doing this the metal, while of similar chemical composition, is much hotter, as consequently is the blow. A saving is also effected of from 7 to 11 per cent. in the coke used, and from 2 to 3 per cent. in the limestone; there are no cupola charges to be met, and the loss of silicon and manganese in the cupola, with a possible enrichment in the sulphur, is also avoided. In this way the saving effected amounts to about 8s. per ton of steel made.

In melting spiegeleisen in a cupola there is a considerable loss of manganese. In one instance the metal before fusion contained 13·50 per cent. of manganese, and afterwards 10·89, the loss of manganese being consequently 2·61 per cent. The composition of the ferro-manganese in use at the Hayingen works for the recarburisation of the ingot metal is as follows:—

Mn.	C.	P.	S.	Si.
60·54	5·38	0·06	traces	3·78

From 2 to 3 per cent. of ferro-manganese is added at these works in the production of an ingot iron containing 0·10 to 0·18 per cent. of carbon. Hæmatite pig iron is used, which contains—

Graphite.	Combined Carbon.	P.	S.	Mn.	Si.
2·74	1·26	0·02	traces	0·21	2·95

This pig iron is employed, in admixture with spiegeleisen, in the production of high-carbon ingot steel. A charge to which 10 per cent. of spiegeleisen, containing 15 per cent. of manganese and 1·4 per cent. of the hæmatite pig iron, had been added, yielded a steel containing 0·47 per cent. of carbon, 0·065 of phosphorus, and 0·80 of manganese. Its tensile strength was 39·3 tons per square inch, with an elongation of 11·5 per cent. All the steelworks around Hayingen use exclusively the limestone found in Namur. This limestone contains less than 1 per cent. of silica. Formerly too much lime used to be added to the charge, but now only about the theoretical quantity is employed. At Hœrde, where the pig iron used contains 0·58 per cent. of silicon, 14 per cent. of limestone is used, whilst the quantity now added at Peine, with a pig iron containing 0·60 per cent. of silicon, is 15·2 per cent. as compared with 19·5 per cent. in 1883. The percentage employed at Hayingen varies with that

of the silicon in the pig iron used, and it amounts to that shown in the following table :—

Percentage of Silicon in Pig Iron.	Percentage of Limestone Charged.
0·3	10·3
0·4	11·6
0·5	12·9
0·6	14·2
0·7	15·5
0·8	17·5

The dephosphorisation diminishes in rapidity with an increase in the temperature of the bath of metal, and it is often necessary, in order to effect the elimination of the phosphorus, to add scrap instead of the limestone, to cool the bath. As a rule the lime is added in a single charge, and before the pig iron is run in. The addition of the limestone in portions at different periods is bad, as it tends to cool the bath to too great an extent. It has been endeavoured to replace a portion of the lime by fluorspar. This makes the slag more thin-fluid, assists the dephosphorisation during the blow, and reduces the loss of metal, but it makes the temperature of the bath fall too low. If enough fluorspar could be added, the afterblow would either be reduced to a minimum or even done without altogether, as Walrand showed in 1884. It is of the utmost importance that the pig iron used should be very regular in composition. If the blow is too hot, or the metal contains over 1·5 per cent. of silicon, 2·5 of manganese, and 2·0 of phosphorus, steel scrap or cold pig iron must be added during the blow. The metal must remain for some time in the converter before pouring, owing to the destructive action it would otherwise exert on the ladle if poured when very hot. The use of old moulds or of burnt scrap causes much of the metal to be ejected during the blow, and the loss is very considerable. Burnt iron has the farther disadvantage that it cools the bath to such an extent that the metal is difficult to pour, and becomes thick in the ladle. When the metal is run into the ladle there is a certain amount of liquation, the lighter and more impure portion rising to the top. Hence it follows that the ingots first cast are the most pure. The percentage of carbon varies but little in the different ingots, but is slightly higher in those ingots which are the last to be cast. The manganese is richer in the first ingot than in the last one, and there is less phosphorus in the first ingot than in the remainder. This is shown by the following analyses :—

Ingot Steel.

Carbon.		Phosphorus.		Manganese.	
Beginning.	End.	Beginning.	End.	Beginning.	End.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
0·38	0·40	0·081	0·146	0·865	0·685
0·43	0·44	0·066	0·091	0·118	0·940
0·41	0·41	0·109	0·130	0·865	0·865
		Ingot Iron.			
0·16	...	0·092	0·117	...	...
0·18	...	0·119	...	0·720	0·470

That portion of the ingot is the most impure where the metal remains longest fluid—that is to say, the centre—the bottom of the ingot being also purer than the top.

M. Palgen gives details as to the cost of manufacture of the ton of basic ingots in Belgium, of which the following is a summary :—

	£	*s.*	*d.*
Pig iron, scrap, and ferro-manganese	2	3	0
Limestone, coke, other fuel, fire-resisting materials, &c., and wages .	0	7	3
Converter bottoms and basic lining	0	1	3
General expenses	0	3	4
Total	£2	14	10

A similar total is arrived at by M. Tordeur, who, taking as a basis for his calculations the prices for coal and coke which ruled in 1892, gives the following total costs at the places mentioned for the ton of basic ingots :—

Works at	£	*s.*	*d.*
Charleroi	2	18	2
Liége	2	15	10
Düdelingen	2	10	10
Longwy	2	14	3

Using soaking pits and reversing engines, the cost of rolling varies for sections not less in weight than 30 lbs. to the running yard from 10s. 5d. to about 12s. On the basis of these calculations, and the selling price of the metal made in March 1892, the average profit was 5s. 7d.

The Decline of the Bessemer Process with Small Converters.—O. Vogel * discusses the decline of this process in the United States. Referring to the out-turn in the United States by the Clapp-Griffith process, he shows that in 1887 the annual capacity of the works then erected was about 204,000 tons, while it has since gradually sunk to about 154,000 tons. As to the Robert process there were 11 converters erected at 7 works in 1889; in 1892 there were only 6 converters at 4 works. The author refers to the comparative advantages and disadvantages of the use of the small Bessemer converter, as compared with the use of the larger one. The small plant, he says, is easy and cheap to erect; it is blown at a low pressure, and much less power is consequently required; it enables small ingots to be cast which can readily be dealt with at small mills; and then there is a fourth advantage claimed, that more phosphorus may be present in the metal, which is stated too to be of better and milder quality. On the other hand, the loss of metal is very high, having proved at the French works to be as much as 20 per cent. in practice. Stead, too, has shown that nine-tenths of the oxidation of the impurities is due to the iron oxide formed in the process, rather than to the direct action of the blast. Garrison and other writers show that this loss varies between 10 and 20 per cent. Again, it is necessary, in order to produce the requisite temperature, either to employ a highly siliceous iron, or else to add ferro-silicon to the molten metal. In the Clapp-Griffith process it is impossible to repair tuyeres during the blow; the metal is apt to be irregular in composition owing to its being exposed in part to the action of the blast when being tapped from the converter, as it is impossible to entirely stop the blast; and samples cannot be taken during the blow, a very important matter. Further, the recarburising material cannot be added in the converter itself; the necessary quantity of scrap to cool the bath is often difficult to charge with the converter; and, finally, it does not appear possible to employ in practice the basic process with small converters, although various patents have been taken out in this direction.

With regard to that modification of the Bessemer process in small converters which comes next in importance to the Clapp-Griffith, the Robert process, the author observes that there is claimed in its favour that the arrangement of the tuyeres is such that while a portion of the blast passes into the metal through the tuyeres, burning the carbon in the bath to carbonic oxide, another portion escapes above the bath of molten metal,

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 44–48, and 57–61.

converting the carbonic oxide into carbonic anhydride. This has undoubtedly as its result an increase in the temperature existing inside the converter, both above the bath as well as of the metal itself, rendering the casting of smaller ingots somewhat easier. The tuyeres, too, are so placed as to cause a rotation of the bath, whereby all the particles of metal are submitted to the oxidising action of the blast with some degree of equality, and a better separation of the metal from slag and from gas is a further result of this rotary movement. The pressure of the blast may also be much smaller, as the tuyeres are placed at the side of the converter and not at the bottom. The loss of metal, too, is stated to be smaller, but this the author doubts, having had figures shown him which reached in the ordinary Robert process as much as 25 per cent. With regard to the other points claimed as favourable to the process, the author considers that the position of the tuyeres high up in the bath is a disadvantage rather than an advantage, in that it leads to an increased loss of the metal by oxidation. The rotary movement of the bath is not novel, though it may possess some advantage in itself. The reduced pressure of blast necessary is an advantage common to all processes of this type.

The author next passes to a consideration of the Walrand-Legénissel modification of the Robert process, in which a miniature Bessemer converter of the ordinary type is employed. If this process is to be carried on successfully the pig iron to be used must contain about 3 per cent. of silicon, although when once the converter has become heated the percentage of silicon may be lowered to about 1·9. If very hot metal is charged into the converter, a corresponding reduction may be made in the silicon in the metal. The metal must, however, be very free from phosphorus, as it is a well-known fact that the reduction in the percentage of phosphorus in the small converter is but very slight. It should not exceed 0·1 per cent. in the metal blown, if metal of good quality is to be made. With regard to the elimination of the impurities present, the author draws attention to the fact that the carbon only disappears in a slight degree at the earlier stage of the blow. In the second stage the graphitic carbon burns, but the combined carbon does not burn until the third stage of the process is reached. The following series of results were obtained by the author from tests made during a blow at the Altsohl works in Austria-Hungary.

The carbon contained in the pig iron was 2·856 per cent. During the various stages of the blow it varied as follows :—

Time from Commencement of the Blow. Minutes.	Carbon. Per Cent.
Six	2·524
Twelve	2·464
Eighteen	2·324
Twenty-four	2·254
Twenty-eight	0·226
In the finished iron after the addition of the ferro-manganese	0·212

With regard to the other impurities the same facts hold true as in the case of a blow in the large converter. Pig iron, which contains from 0·06 to 0·1 per cent. of copper, will yield an ingot metal of satisfactory quality provided the other impurities are not present in too large quantities. The main point to be borne in mind is that the metal must come at a very high temperature from the cupola. Before everything, however, the main basis of success in the small Bessemer process lies in the use of a pig iron of a regular character and suitable chemical composition. That being the case, it is a matter of ease to blow charge after charge without interruption, and to produce an ingot metal which leaves little to be desired. The loss of heat will be little, the sculls in the ladle slight, and the waste metal can be used over again as scrap in cooling the bath. If, on the other hand, the pig iron is not of a suitable quality all kinds of difficulties will be experienced. With some little care, however, it is nearly always possible to mix the pig iron charge in such a manner that it shall not only blow readily, but that a thin fluid slag shall be also formed. The bath must be hot if the results are to be satisfactory. The author is of opinion that the basic open-hearth process is always preferable to this form of the Bessemer process.

The Shenango Valley Bessemer Works.—The works of this company are situated at Newcastle, Pennsylvania,* and are of recent construction. The plant consists of two 8-ton converters, served by three 10-ton cupolas, arranged for the possible use of direct metal. The pit system of casting is adhered to, the ingots being transferred to two 5-hole soaking pits placed close to the casting pit. A 36-inch blooming mill forms part of the plant, a new feature in which is the introduction of a large hydraulic shear placed midway between the mill and the blooming mill shear proper, thus enabling a billet to be cut in halves, and both pieces either transferred at once to the main shear, or one piece to the auxiliary billet mill. The blowing engines consist of two vertical engines with 42-inch steam cylinders and 60-inch blowing cylinders,

* *Iron Age*, vol. l. p. 676, with sheet of illustrations.

with strokes of 60 inches. The heating furnaces are fitted with disc reversing valves, thus doing away with the older or "butterfly" valves. The converters, measured from the centre of the trunnion, are placed at an elevation of about fourteen feet above the general level, enabling a waggon to be run under the nose of the converter when it is being tipped. The melted metal truck running in front of the converter is actuated by a wire rope. The cupolas are so arranged that they practically commence at the level of the charging floor, only a kind of hood existing above it, thus affording great facility for charging. The distance from the blooming mill to the main shears is 100 feet, sufficient to admit of a 2-ton ingot being rolled down to 4 by 4 inches, and sheared without interfering with the rolling of the succeeding ingots.

The Basic Bessemer Plant of the Pottstown Works.—A detailed description of the basic Bessemer plant of the Pottstown Iron Company, with a full description of their practice, is given by Mr. J. Hartshorne.* The basic slag is ground in a ball mill requiring 13 horse-power to drive it. The average output is 20,000 lbs. in ten hours, 70 to 75 per cent. passing through a 150-mesh sieve. The brick-making plant consists of two Gates' breakers, a 96-inch Fisher chaser mill, elevators, dry and wet mixers, and a brick-making machine. The bricks are made direct from limestone, and are fired wet without previous calcination, thereby preventing admixture of ash from the coke. The ovens hold 5000 bricks, or 14,000 lbs. per charge, which is fired for 36 to 38 hours, with a consumption of 2700 lbs. of fuel per ton of burnt bricks. Two continuous limekilns are at present in use. They are 9 feet in diameter, 30 feet high above the furnace, and 8 feet below. External furnaces are used, and the fuel consumption is 300 lbs. of coal per ton of lime, 25,000 lbs. being burnt per twenty-four hours.

Two Wellman producers supply gas for an open-hearth furnace, in which the ordinary pig and scrap process is carried on.

Adjacent to this plant is the grinding and mixing plant for the basic material. The brick is crushed and ground in a Gates' breaker and a mill, and after sifting is mixed with 10 to 12 per cent. of hot tar.

Two cupolas, a third being in the course of erection, are used for melting. They are 10 feet in diameter, and 24 feet high from the charging door to the tapping hole. They have nineteen 6-inch tuyeres 4 feet above the tapping hole, and are fitted with the Greiner attach-

* *Transactions of the American Institute of Mining Engineers*, October 1892 (advance proof).

ment. They tap into a central ladle on a weighing machine. Between the cupolas are the ferro-manganese heating furnaces, which were originally used for heating lime, but at the present time the lime is used cold.

There are three converters, two of 10 tons and one of 13 tons. They are 10 feet in diameter at the trunnions and 17 feet high, the greater capacity of the larger being due to its shape, which is found to be preferable to that of the other two. The lining averages 15 inches in thickness. The bottom has 17 tuyeres 24 inches long, each with seven $\frac{11}{16}$-inch holes. It takes thirty-six hours to ram a vessel, and the average life of the lining is 150 heats. No details are available of the life of the bottom, but they are supposed to average 800 to 1000 heats, as they are patched with slurry after renewing the tuyeres. Two cranes are placed between the vessels for handling the ladles and for transferring them to a travelling casting crane. The casting-pit is straight, and is at right angles to the converting-house. The ingots vary in weight from 3000 to 7000 lbs., averaging 5500 lbs.

The blooming train is 36 inches between centres, with 30-inch rolls, and a rise of 32-inch for edging slabs. The ingots are heated in three upright or Hainsworth furnaces with eight pits altogether. A short description of the other parts of the mill and of the boilers and other appurtenances is also given.

The practice in use was originally developed by Mr. E. Bertrand, now at Kladno. The pig iron used contains:—

Silicon.	Sulphur.	Manganese.	Phosphorus.
0·5	0·02 to 0·04	0·8	2·50 to 3·00

From 11·5 to 13·0 per cent. of lime is charged into the converter, and the melted pig iron is run in as hot as possible. The blast pressure is maintained at 28 to 30 lbs. per square inch, and the speed of the engine is kept constant. In connection with the engines are two sets of revolution counters, one set being used during the fore-blow, and the other during the after-blow. The second set is thrown into gear when the charge comes, and the length of the after-blow is determined by the number of revolutions. The first part of the blow is made as hot as possible, and then the metal is cooled so that it can only just be cast without skulling, in order to obtain a viscous slag, and to prevent the phosphorus repassing into the metal. The blow is determined by the spectroscope. With the average charge of 26,000 lbs., the fore-blow lasts 11 minutes, and the after-blow 5 minutes. As the vessel is turned down, from 0·6 to 0·8 per

cent. of 80 per cent. ferro-manganese is added, and after two-thirds of the charge is poured from 1 to 1·5 per cent. of a 10 per cent. spiegeleisen is thrown into the ladle. Casting is done slowly, metal being also continuously added as it sinks in the mould to obtain solid ingots. The metal rarely rises in the mould. A simple cast iron plug without sand is used as a capping.

During casting two 4-inch 50 lb. ingots are made for testing. These are forged down at a white heat to $1\frac{1}{4}$ inch square. Two 8-inch lengths are cut off, one is chilled, and the other cooled slowly from a cherry red. Each bar is laid on a V-shaped opening 5 inches wide and $2\frac{1}{4}$ inches deep, and is then struck light uniform blows by a 650 lb. drop hammer till bent down into the V. It is then reversed, and the process continued until the bar is broken. Cracks and fracture are observed, and from the latter the percentage of phosphorus may be told to within 0·01 per cent. The remainder of the ingot is forged down to $\frac{5}{8}$-inch square, and cut into three 10-inch lengths. One of these is chilled, and another cooled slowly. Each of these two is nicked and broken, the longer portion of each being bent in a machine to grade the metal for softness. These tests are confirmatory of the previous two. The third piece is reserved for testing red shortness by a combination bending and drifting process at a bright cherry red heat. These tests not only indicate the quality of the metal, but from them can be determined with great accuracy the duration of blow and the amount of recarburisers required for the next charge. Besides these tests, carbon, manganese, and phosphorus are determined chemically in each heat, and sulphur in every fourth heat.

In conclusion the author gives tables showing the results of consecutive blows.

Basic Slag as Manure.—Dr. M. A. von Reis * finds that hard slags contain more ferric oxide than soft slags which are produced by slow cooling, and are therefore preferable for manurial purposes. This fact is ascribed to the decomposition of calcium ferrate when the slag cools slowly. On solution in dilute hydrochloric acid, the softer slags give a greater amount of residue of ferric oxide, and the quantity that is left is a sign of the ease with which the slag can be ground.

* *Zeitschrift für Angewandte Chemie*, 1892, pp. 229-231.

IV.—*OTHER PROCESSES.*

The Conley Direct Reduction Process.—Mr. N. R. Conley* has devised a furnace with a view to avoid the re-oxidation of the reduced iron. It consists of an open-hearth furnace slightly modified in detail, and provided with horizontal retorts into which the ore is charged. When the ore is reduced, the contents of the retorts are discharged directly on to the bed of the open hearth.

Direct Processes.—The Eames and the Adams-Blair direct processes are described by E. de Billy† as he saw them at work at Pittsburgh in 1891. By the Eames process the ore is reduced in a reverberatory furnace at a temperature approaching that in the puddling furnace, and the resulting sponge is balled, squeezed, and passed to an open-hearth furnace, or direct to the rolls. The ores employed were a mixture of hard magnetite and soft hæmatite, containing about 65 per cent. of iron and 5 to 6 per cent. of silica. Coke or carbon produced by the partial combustion of natural gas is employed as a reducing agent, and to prevent its too rapid combustion it is washed or coated with milk of lime. The ore and carbon, in the proportion of four to one, are ground together with sufficient water, so that the mixture can be moulded by hand. The reverberatory furnace has a rectangular hearth 15¾ feet long by 4½ feet wide, with a low arched roof, and natural gas is employed as fuel. Four furnaces are grouped together. The hearth is made with graphitic anthracite and coke, a layer of ore being fritted on. The charge is about 1¼ ton, and is spread in a layer about 3½ inches in thickness. The doors are sealed and the temperature is raised. After about an hour and a half, when the layer has shrunk to a third of its thickness, the doors are opened and the metal is balled. If the blooms are to be transferred to an open-hearth furnace, the temperature is raised from about 540° C. to 800° C. in about half an hour, but if they are to be rolled the temperature is much greater, and the balling is carried on as in the puddling process to remove as much cinder as possible, an hour being then required. The blooms are shingled, rolled, piled and re-rolled. The practice now adopted is to roll part of the blooms, and to charge the rest, after cooling, into the open-hearth furnace. The product contains—

* *Iron Age*, vol. li. p. 415, one illustration.

† *Annales des Mines*, 9th series, vol. ii. pp. 329-351, with one plate.

	P.	S.	C.
Blooms	0·018	0·020	0·05
Bar iron after re-rolling . .	0·010	0·010	0·05

The slag contains 24 to 30 per cent. of silica and 30 to 50 per cent. of iron. The loss of iron is high, but has been reduced to 15 per cent. The quality of the product is good, and the process is economical.

In the Adams process the ore is reduced to a sponge by natural gas at a temperature of about 800° C., and is charged almost direct into an open-hearth furnace by means of a shoot. The reducing chambers are vertical, and are placed in groups of four over the furnace. The gas is led through the ore, and then is burnt in passages surrounding the chambers. The ore is charged in lumps the size of the doubled fist, and is reduced in about an hour and a half. The shape of the lumps is preserved, but while the iron is reduced the gangue is not melted until it is introduced into the furnace. A basic open-hearth is used, so that the phosphorus is kept in the slag. The practice is to discharge the four chambers into the hearth, then to add and melt the pig iron, and subsequently to discharge the recharged chambers one at a time into the bath, tapping off the slag from time to time as it clears. One of pig iron to two parts of ore has been successfully employed. This process appears to be preferable to the first one, as the fuel is employed to better advantage in the chambers than in a reverberatory furnace.

FURTHER TREATMENT OF IRON AND STEEL.

Old Ironwork.—Mr. C. J. Hart* has recently described the old ironwork to be found in Warwickshire, dating from the twelfth to the end of the eighteenth century. From very early days this country was an ironworking centre. This was to be accounted for by the proximity of the Forest of Arden, which occupied a large portion of the middle of the county, and supplied abundance of charcoal. Much ironwork had been lost through its perishable nature, as it was often not painted, besides which, the Commonwealth was accountable for much destruction. Illustrations were given of specimens of old ironwork from a large number of churches, and their peculiarities were explained.

Malleable Iron Castings.—Malleable cast iron, according to Mr. S. Bolland,† is in an intermediate state between grey iron and steel, possessing a higher tenacity, with increased toughness, than the former, but differing from the latter in having a lower ductility, less tenacity, and in containing graphitic carbon. Malleable cast iron can be hardened, but cannot be reliably tempered. At a moderate red heat it is possible to forge some of the best qualities, but if it is overheated it crumbles away as soon as it is struck. Owing to the non-removal of constituents other than carbon, it is essential that a fairly pure cast iron be employed if it is desired to obtain a good malleable metal. English firms prefer the various brands of hæmatite, whilst in America the several brands of unquestionably good charcoal iron are selected. The mottled irons are invariably preferred for this purpose. Soft grey iron gives weak castings when the graphitic carbon is removed. The white irons would be the best, having all their carbon in the state of chemical combination, but they have not sufficient fluidity. Medium or mottled irons are some-

* Paper read before the Birmingham and Midland Institute, March 22, 1893.

† *American Machinist*, vol. xvi. No. 2.

times further strengthened by the addition of steel or of wrought scrap, the proportions of which alloys can only be determined by close observation and constant practice. Mr. C. Wylie mentions the successful use of old fire-bars. The moulding for malleable casting is practically the same as for other work, only perhaps it is more perfectly done. The gates are larger, as the metal is less fluid. Both the cupola and crucibles are used for melting, but it is preferable to use the reverberatory furnace, as the metal is partly deoxidised, and is kept free from impurities. The Siemens regenerative pot-furnace is often used.

With some few slight modifications the cementing furnace for producing blister steel will answer the purpose of annealing or decarburising cast iron. Some of the late improvements provide for the flame passing all round the chamber without coming into actual contact with the boxes containing the castings to be annealed. Access to this chamber is obtained at one end, where the boxes can be inserted, or withdrawn at any time without interfering with the continuous working of the furnace.

The Siemens regenerative system is much used for the annealing furnace as well as for melting with. As arranged for this purpose, the furnace has four longitudinal main flues, divided by partitions into a number of smaller flues; the two exterior flues receive the heated gas, and the two interior ones the hot air. Over these is a closed arch muffle, in which the annealing boxes are placed. The hot gas and the hot air pass beneath at the sides and over the top of the arch of the muffle. The furnace is never permitted to cool entirely, the boxes being allowed to cool on the floor. It is necessary that all castings, previous to being placed in the annealing boxes, should be freed from every particle of sand; this is done either by abrasion in the tumbling barrel, by scrubbing with wire brushes, or by pickling in dilute sulphuric acid. If the latter method is adopted, the castings should be thoroughly washed and dried before being placed in the annealing boxes. The annealing boxes are usually cast iron of the same nature as the castings to be annealed in them. For ordinary purposes they are about 13 inches in depth and width, and about 16 inches long, and if carefully used they will last from fifteen to twenty heats. For heavier and larger pieces, special boxes are made to suit the requirements, wrought iron sometimes being used for the purpose; but these latter warp and twist out of shape in a very short time. Either a pure red hæmatite ore, as free as possible from all earthy matter, or smithy and rolling-mill scales are used to supply oxygen for the removal of the carbon. The completeness of this action depends

on the duration of the heating, the carbon in the outer layers disappearing first.

The iron ore is sometimes objectionable, as the earthy matter which is mixed with it fuses, and adheres to the castings in the form of scoria. This not only interferes with the decarburising of the casting, but requires to be scrubbed off by a second hard application of the tumbling barrel. On the other hand, the scales are entirely free from such impurities, and do not interfere with the legitimate operations of annealing. As the scales lose some of their oxidising properties at every heat, they are reoxidised by the application of dilute sal-ammoniac, and allowing them to rust again. By this means they can be used over and over again along with the new, which is added to make good the waste. When ore is used, it is previously ground and sifted; what passes through an $\frac{1}{8}$-inch sieve is rejected, as it contains too much earthy matter.

Packing the boxes is an important part of the annealing process. A quantity of the ore or scales is first placed on the bottom, on which, separate from each other, the first layer of castings is placed. These are then covered to a depth of $\frac{3}{4}$ inch with the ore or scales, on which the second layer of castings is placed, separate as before, and the operation continued until the box is nearly full, when the lid is carefully set in, resting on a final layer of the ore or scales. The covers are carefully luted to prevent the admission of air. The boxes are usually inserted into the oven in pairs. Long practice on the part of the furnace-man qualifies him for judging how long a time each kind of casting requires for complete decarburisation; the heaviest are assigned to the hottest parts of the furnace, marked in such a manner as will enable him to give to each class a period of heat proportionate to the bulk. For these reasons it is customary to place the castings in each box as near alike in bulk as possible.

The oxide which forms on the castings during the process of decarburising is a trustworthy indicator of the quality or degree of malleability obtained, the operator being able to judge of this according to the hues presented. No matter how clean the scales may have been, all castings after being taken from the furnace require more or less cleaning to make them at all presentable.

The capacity of annealing furnaces varies somewhat, but they usually treat from 650 to 1200 lbs. at one heat. The length of time required is from two days to two weeks, according to bulk, but they must not be kept at too high a temperature, nor remain too long, or the result will be

the opposite to what is desired—the castings will be hard instead of soft. Usually the heat is gradually slackened for about fifteen hours before taking out the boxes, and the latter are allowed to become cold before taking out the castings.

Steel Castings.—S. Kern * states that steel castings are made at several works in Russia. Open-hearth steel is generally employed, but at several works only crucible steel is used—as, for instance, at the Obouchoff Works, near St. Petersburg. Here coke-furnaces are used, each holding four crucibles. For casting naval gun-carriages, the charge for each crucible was 40 lbs. of puddled iron, containing 0·12 per cent. of carbon, and an equal weight of puddled steel containing 0·45 to 0·50 per cent. of carbon. To this charge from one-half to three-quarters of a pound of ferro-manganese containing 70 per cent. of manganese was added. In about 4½ hours the charge was melted. This done, 2½ lbs. of ferro-silicon containing 7 per cent. of silicon was charged in through an iron funnel, and the metal was then cast in about twenty minutes. The moulding sand was prepared from a mixture of 85 per cent. of a white quartz sand with 15 per cent. of fireclay and a small quantity of rye flour, the latter rendering the moulds porous after being heated in the drying-stove. At the Poutiloff Ironworks, for castings up to 360 lbs. in weight, crucible steel is used, while for heavier castings open-hearth metal is employed. The metal used at these works for the stem and stern posts of a gunboat recently constructed there contained—

	C.	Mn.	Si.	P.	S.
Stem . . .	0·13	0·50	0·27	0·03	0·02
Stern . . .	0·15	0·45	0·25	0·04	0·02

The mechanical tests showed respectively tensile strengths of 32·5 and 34·8 tons per square inch, and elongations of 12·3 and 11·2 per cent. on 8 inches. By using silicon-spiegeleisen containing 10 per cent. of silicon and 12 per cent. of manganese, sound and good castings are always obtained. After casting, the metal should contain 0·25 to 0·30 per cent. of silicon.

The Lauth Heating Furnace.—Drawings are published of this furnace, which is arranged for coal-firing. The roof slopes upwards rapidly from the grate to the flue end of the furnace, while the flue opening is placed very low down. This arrangement is stated to give a

* *Chemical News*, vol. lxvii. p. 104.

better and more general heating than is possible in the ordinary form of heating furnace, the metal near the fire-bridge being also less exposed to the direct action of the flame.*

Hydraulic Power in the Manufacture of Iron and Steel.—Mr. J. L. Biggart† describes the adaptation of hydraulic power in the manufacture of iron and steel. Frost is guarded against by putting all the pipes underground, or by using an admixture of glycerine in the water. In Scotland from 40 to 50 per cent. of glycerine has to be used under unfavourable conditions. To avoid friction, the water should be clean, and lubricants should be used. When accumulators are not in use, three throw-pumps give the steadiest stream of water, but a set of four is sometimes employed. For heavy pressures, a multiplier is used. The form of the accumulators and of the distributing pipes is then discussed, and considerable attention is paid to the valves. The author next describes the various appliances in which the water under pressure is used. Commencing with cranes, the various forms are briefly commented upon, and then hydraulic lifts for ladle-tipping purposes are described. For tilting converters two forms of gearing are used, worm and rack gearing. The latter is safe if a check-valve is inserted in the pipes. A shearing-machine with two rams is then described, and the application of hydraulic power to testing-machines is set forth, many other applications being also mentioned. In the discussion which ensued, further applications were referred to.

Taper-Rolling Machine.—Illustrations have appeared‡ of an American machine designed for rolling flat tapers on round, square, and flat bars of steel of large section. It is fitted with plain flat dies, which work in combination with a squeezing or edging arrangement. With the same dies the machine can be adjusted to taper 6 inches by ½ inch flats, and all sizes of rounds, flats, and squares under these dimensions. The upper and lower rolls are cut away to receive the dies.

The bar to be tapered is passed in between the roll-dies, just before they come into operative position, and pressed forward until it comes in contact with one of several adjustable stops, where the dies grip the bar and return it to the starting-point, at the same time rolling the taper.

* *American Manufacturer*, vol. lii. p. 99, six illustrations.

† Paper read before the West of Scotland Iron and Steel Association, January 13, 1893.

‡ *Iron Age*, vol. l. p. 1027.

Each stop is set farther back than the preceding one, so as to increase the length of taper.

After being passed between the rolls the bar is squeezed sideways and shaped as desired by means of a fixed die, or a series of dies placed one above the other in the form of steps, the width and shape of these dies varying to produce any required width and shape of taper, all of which is arranged on a slide, which moves upon a plate forming part of the machine. This squeezer mechanism is driven by a pair of bevel wheels from the main back-shaft, and is timed with the rolls. The rolls are 14 inches in diameter, 18 inches between the housings, and are geared 4 to 1.

Re-rolling Old Steel Rails.—Mr. S. M'Cloud* has devised a method of re-rolling old steel rails into flat plates, which has been adopted at several rolling-mills. In the older methods the rails were split into three parts, the head, the web, and the base. These were then heated and rolled into shapes suitable for their size. In the M'Cloud process the rail is rolled in its entirety. Only heavy rail sections are taken, those from 56 lbs. upwards. These are selected with some care, no rail with a split end being taken. The rails are cut into lengths of from 3 to 6 feet, heated in the ordinary way, and then passed endwise through a set of specially prepared rolls, which gradually flatten both the head and the flange of the rail without permitting any folding, as the steel would not weld. Six passes and one heat are sufficient, the appearance of the rail after each pass being shown by illustrations. The plates are rolled about $\frac{1}{4}$ inch in thickness and 8 to 10 inches in width.

Rolling "Wrapped Steel" Plates.—Illustrations have been published† of a special set of rolls for wrapping up or folding longitudinally steel plates into billets. The process is devised by Mr. S. M'Cloud. The plate is first passed between two horizontal rolls, which bend it to a semicircular section, vertical rolls then further compress the sides, and the work is passed through a guide or former, which turns the V-section into a bar with a spiral section. A further set of rolls, in line with the previous devices, then compresses the billet to square form. At the Peoria Steelworks plates 0·25 inch in thickness are wrapped or rolled lengthwise. The plate of metal as it passes from the reducing rolls goes to other rolls, which gives to the plate a concave-convex

* *Iron Age*, vol. l. p. 882; *Engineering and Mining Journal*, vol. liv. pp. 608-609.
† *Engineering and Mining Journal*, vol. liv. p. 609.

shape. These rolls are driven by means of a ratchet wheel and pawls, giving them a high rate of speed. The metal next passes between guide rolls which bend up the edges of the metal plate and direct it into the flaring mouth of the "former." Thence it passes to reducing rolls until the metal is compressed into the finished forms desired. The description of this process is accompanied by illustrations of the plates.*

Electric Hardening.—Professor Lagrange and P. Hoho† describe some researches on the luminous sheath which surrounds a fine wire when used as a negative electrode in an electrolytic vessel through which a current of high electromotive force and small quantity is passing. This sheath is not only luminous, but is also very hot, the heat being extremely local. A piece of iron 10 centimetres long and 1 centimetre in diameter can be heated by proper arrangement of non-conducting screens in alternate centimetre long sections, the heated sections joining whilst the others are quite cold. So rapid is the heating, that a rod of iron can be made white hot at the surface before the interior is affected, and thus by suddenly making and breaking a circuit, the surface of a piece of iron can be suddenly heated up and then quenched in the electrolyte. An exceedingly hard coating is thus obtained, the depth of which depends on the duration of the process. The authors showed samples of iron which had been treated in this way, and which exhibited totally different fractures at the surface and in the interior. Electric hardening has been in use for some years, but this process seems to permit the hardening of very fine springs, and promises to be useful in case-hardening.

Electric Welding.—Mr. F. P. Royce‡ describes the development that has taken place in the electrical working of metals, commencing with a description of some of the various processes of welding now in vogue. At Johnstown in Pennsylvania several hundred large welds are made daily. As much as ten square inches of iron or steel are welded together, a pressure of 150 tons being applied by a hydraulic press to reduce the burr and finish the work. Five of the welders are used for rail work and weigh thirty tons each. The various materials and shapes that can be welded are referred to. The question of cost is also discussed, the quantity of work that can be turned out, and the limited amount of

* *Iron Age*, vol. l. pp. 882–883, thirteen illustrations.
† *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. pp. 575–577.
‡ Paper read before the Carriage Builders' National Association, Buffalo Meeting.

labour required for it being described. In connection with waggon-work, it has been found most economical to reduce the burr at the weld by hammering, grinding being found too expensive and rolling impracticable. The weld retains sufficient heat after removal from the machine to allow the hammering to be properly performed, besides which the quality of the material is improved by the work put into it. Power presses have been found efficient for some kinds of welds. It is only in exceptional cases, where the work is very rusty, that it need be cleaned. All that is required is a slight increase of power to overcome the resistance. The following table shows the power and time for welding:—

Work.	Horse-Power.	Seconds.
1-inch round axle	25	45
1-inch square axle	30	48
1¼-inch round axle	35	60
1¼-inch square axle	40	70
2-inch round axle	75	95
2-inch square axle	90	100
1 × $\frac{1}{16}$-inch tire	11	15
1½ × $\frac{5}{8}$-inch tire	23	25
1½ × $\frac{5}{8}$-inch tire	20	30
1½ × ¾-inch tire	23	40
2 × ½-inch tire	29	55
2 × ¾-inch tire	42	62

The increased time for the squares over that for the rounds is due to the necessity for carefully aligning the pieces. The time given above is simply that during which the current is being passed. It has been found that the cost of fuel required for electric welding and for forge-heating is about the same. Most welds are butt-welds, but with some special kinds of tire steel lap-welds heated by the current and finished by hammering are used. Welding for irregular forms is also mentioned.

Mr. N. H. Watkinson * describes the application of electricity to heating and welding metals, and describes the several methods now in use. Tables are given to show the superiority, both with regard to cost and to efficiency, of electric welding over ordinary welding.

Mr. G. Richard † in a series of articles deals with the various forms of apparatus and the different methods used in electric welding. The apparatus used are illustrated, and the articles summarise the various recently patented forms.

* Paper read before the Physical Society of Glasgow University.

† *La Lumière Electrique*, vol. xliii. p. 356, vol. xliv. p. 353, vol. xlvi. p. 114.

Welding Nickel and Steel.—In the course of the discussion on a paper on the world's supply of nickel by Mr. J. H. Eastwick,* the question of welding nickel and iron was mentioned by Mr. Mixer. In rolled sheets of nickel and steel made at Cleveland, Ohio, it was not possible to find the line of demarcation between the metals. The nickel is welded to both sides of a sheet of steel, and makes a non-oxidisable metal with the stiffness of steel. A bar of nickel steel containing 25 per cent. of nickel is very tough and takes a high polish.

The Manufacture of Tubes.—The manufacture of seamless steel tubes is carried on at the works of the Kellogg Company, of Findlay, Ohio. Illustrations of the rolling-mill employed for this purpose appear in the *Iron Age*.† The method employed is as follows:—A hollow ingot of adequate size is first cast. Those usually cast are 3 feet 6 inches long, with an internal diameter of from 4 to 5 inches, and a thickness of metal of $\frac{3}{4}$ inch. Great care is taken when casting to place the cores in the exact centre of the moulds, so that a uniform thickness of metal may be secured throughout the shell. The cores are collapsable, and are removed as soon as the steel has set in order to prevent the ingots from bursting, which was found to occur frequently if they were allowed to cool around a solid core. A kind of hen-and-chicken method of casting is employed. The apparatus used in rolling the ingots into tubes has two sets of reducing rolls. The heated ingot is placed in a cradle. A mandrel, with cast iron balls on it at definite distances, and which is placed on the arbour bed in line with the centre of the ingot, is then driven forward by a piston working in a long horizontal steam-cylinder 27 feet in length. As soon as the mandrel is in place, another pusher cylinder below is brought into use, which forces the ingot forward into the rolls. Five pairs of rolls then come into action, three pairs being arranged horizontally and two vertically. These rolls are grooved, and are 16 inches in diameter, all being driven by one 600 horse-power engine, with cogged gearing. The metal of the ingot is reduced evenly at every point in passing through these rolls, but the reduction is only partial. The tube then passes into a conveyer on the farther side of the rolls, which takes it to a straightener of the usual type. The next step is to take the tube to a heating furnace on the other side of the machine. After it is heated it is subjected to a precisely similar operation, the only difference consisting in the rolls on that side, which have smaller grooves, to reduce

* *Proceedings of the Engineers' Society of Western Pennsylvania.*

† Vol. l. pp. 563-565, five illustrations.

the metal further. The limit of the process, with the machinery as yet built, is tubes of about 1½ inch in diameter and 16 feet in length.

Mr. W. H. Barraclough * describes the uses of the Mannesmann tubes and the method of their manufacture. Various explanations of the action are given, and the machinery in use at Landore is described. Tests of the tubes compared with welded or cast pipes are appended.

Mr. G. R. Green † describes the various forms through which machinery for the manufacture of spirally welded tubing has passed. For some nine or ten years prior to 1887 Mr. J. B. Root had experimented on this subject, and in the previous year had constructed a machine in which a few feet of tube could be produced from a skelp. After a short length of tube was made, however, the feeding and other parts refused to act, and many modifications had to be introduced. Some of these are described by the author, and a description is given of the type of machine which is now in successful use, and is turning out pipe far beyond the estimated capacity. An improved type of double draw-bench for making solid-drawn seamless steel tubes has recently been illustrated.‡

The Manufacture of Wire.—Mr. G. P. Clapp § describes the method of manufacture of Bessemer steel wire. All the finer grades of wire are produced from No. 5 or No. 6 rod. Analyses of two different grades of rods showed :—

Elements.	I.	II.
	Per Cent.	Per Cent.
Carbon	0·089	0·075
Silicon	0·008	traces
Phosphorus	0·068	0·055
Sulphur	0·076	0·043
Manganese	0·446	0·216
Copper	0·032	0·032
Iron	99·342	99·600
Total	100·061	100·021

The material represented by I. made wire of excellent quality, whilst the metal II. was not only brittle but inferior in every way. It was

* Paper read before the Mason College Engineering Society, December 7, 1892, through *The Engineer*, vol. lxxiv. p. 540.

† *Journal of the Franklin Institute*, vol. cxxxiii. pp. 176–186, with illustrations.

‡ *Iron and Coal Trades Review*, vol. xlvi. p. 619.

§ *Iron Age*, vol. l. pp. 576–577.

apparently deficient in manganese for the percentage of carbon present. Wire rods should not contain more than 0·1 per cent. of phosphorus, and practically no sulphur nor phosphorus. When the rods or bundles are well opened, they should be placed in tubs or tanks containing a mixture of 1 gallon of sulphuric acid to 100 gallons of water, and raised to a temperature of 160° F. This will remove the scale. In half an hour the rods should be removed and dipped in a very weak solution of acid and cold water, and then placed on the floor and kept wet by sprinkling. Within a few minutes a dark-green slimy coating will form on the rods. This will gradually turn brown, and it acts as a protecting layer between the raw surface of the wire and the drawing die. Indeed, to have the rod clean and properly coated is one of the chief elements of success in drawing from No. 5 to No. 13 without annealing. For one holing to No. 8½ or No. 9, scarcely any coating is necessary, but to draw to No. 13 in four drafts, great care must be observed, and from one half to one hour is required to form a proper coating, according to the quality of the material, the time required increasing with the percentage of the carbon. When the rods are adequately coated they should be dipped in boiling lime-water, and must be removed quickly to avoid the protecting coating being impaired. They should then be taken directly to the drawing benches. Thirty-five lbs. of sulphuric acid of 66° B. is sufficient to clean 1 ton of rods, while 60 lbs. is sufficient to clean 1 ton of fine wire. In drawing to No. 13, the wire should be annealed at No. 8 or 10. Reducing the wire too much before annealing causes crystallisation, and the wire continues hard and brittle after annealing.

The most approved process for making the finer grades of wire is by the "liquor bright process," as follows:—First anneal and clean No. 13 in sulphuric acid, about the same as the rods, with the exception that the acid and water should not be heated to more than 130°. A greater heat is likely to turn the wire black, which is not desirable. After thoroughly washing, place the wire in the baking-oven until the acid is thoroughly evaporated and red oxide is formed on the wire, then dip in the sulphuric mixture for about two minutes, then wash and dip immediately in cold lime-water. Next place it in the "baker" for an hour or two, and then draw in lime bright, in one hole, to No. 14. Next place the wire in clean water and soak for twelve hours or more. This softens what grease remains on the wire and allows the sulphate of copper to take the wire readily. The copper coating preparation is made as follows:—Dissolve 10 lbs. of sulphate of copper by boiling in water, mix with 5 gallons of rye-flour and water, 4 quarts of sulphuric acid, and 18

gallons of soft water. Place the wire to be drawn in this mixture for about two minutes, rinse in clean water, then put it on a reel in a tub of rye-flour and water and draw down to size required. When the water is hard, add a small quantity of carbonate of soda. The sulphate of copper and acid have a tendency to make the drawing surface of the wire rough and hard and the rye-flour is used to neutralise these conditions. More and better wire can be drawn down to No. 24 by the above process than by any other.

Wire deficient in carbon and manganese will have a black greasy deposit remaining on the wire after cleaning, which is hard to remove, while wire containing sufficient of these elements will clean easily and make good wire for galvanising, coppering, and other purposes.

Forging and Stamping.—An illustration is given * of a forging machine for round shapes, such as spheres, bolts, tool-handles, &c., from half an inch up to 6 inches in diameter. A red-hot bar is placed between revolving dies, which are driven by powerful gearing, and at each revolution an article is produced.

Illustrations † have appeared of a new design of forging and bending machine. It is designed more especially as a forging machine, though it will bend as well. It has an adjustable stroke, and the bed being of considerable strength, the bending can be effected in the cold. The die-plate has a depression in the jaw, into which the bottom of the die drops. The die is adjusted by a wedge-block, which will resist heavy strain without injury to screws supporting the die. The machine can be stopped by a pawl at the extremity of its backward stroke. Indeed, it can be made to stop automatically at any point, and may be driven by steam direct.

Mr. B. F. Spalding ‡ discusses the reasons for the cracks and faults that develop in steel dies which are used for stamping hot metal, and ascribes them to the irregular expansion and contraction of the metal. It would seem that a steel comparatively low in carbon, and yet capable of being sufficiently hardened, is best suited for the purpose.

Planing Machines.—Illustrations including a part side elevation of a very large and comprehensive table-planing machine have been given.§ It is capable of planing a block 30 feet long, 12 feet wide, and

* *Engineering and Mining Journal*, vol. lv. p. 105.
† *Iron Age*, vol. l. p. 768.
‡ *American Machinist*, vol. xvi. No. 6.
§ *The Engineer*, vol. lxxv. p. 162.

10 feet high with four tools, two at the top and one at each side. One of the tools on the side has also a cross-planing motion for planing the ends. The tool-boxes are reversible, so as to cut on both strokes. The bed of the machine is 45 feet long, and has the two uprights bolted to it. There are three V-guides and a rack driving-gear. The table is made in two parts, with a single traverse-joint, so that half the table only is used for small work.

An illustration is given * of a vertical and horizontal planing machine for large castings. The bed is of box section, and carries compound slides and a rotating table. The vertical column on which the tool moves vertically is carried by two horizontal slides on a casting at one side of the bed.

Illustrations are given of a double planing machine which consists practically of two open-side planes arranged in such a manner that they may either be used separately or jointly, if the work is too large for one plane alone. It consists of two beds bolted together, the platens of which are driven independently. There is also a tool carriage for each side.†

Boring and Drilling Machines.—A heavy multiple radial arm drilling machine has recently been illustrated.‡ It has three 7-foot radial arm drilling machines.

A horizontal cylinder-boring machine made by a Halifax company is illustrated.§ It is capable of boring up to 18 inches in diameter, and 42 inches long at a maximum height of 30 inches above the bed.

Drawings are published || of a 14-foot mill of this type constructed by the Belts Machine Company of Wilmington, Delaware. The machine consists essentially of a bed-plate carrying a rotating table or face-plate, two uprights or standards, a cross-rail carrying two saddles with their tool spindles and attachments, and the necessary driving mechanism. The table is driven by an internal spur wheel and a forged steel pinion.

Punching and Cutting Machines.—An illustration is given ¶ of an oval hole-punching machine adapted to punch holes up to 21 by 16 inches. The top and bottom dies are of iron, steel faced, and the table

* *Engineering*, vol. liv. pp. 771, 780.
† *Iron Age*, vol. li. p. 61, three illustrations.
‡ *The Engineer*, vol. lxxiv. p. 478.
§ *Industries*, vol. xiv. pp. 28–29.
|| *Iron Age*, vol. l. p. 663, seven illustrations.
¶ *Engineering*, vol. lv. pp. 376 and 379.

is fitted with rollers over which the work travels. Two adjustable strippers are fitted in the head. The whole machine is contained in a pit in the floor of the workshop, from which it is raised by two hydraulic rams only when it is required.

An illustration of a pipe-cutting and threading machine appears in the *Iron Age*.* This machine is so constructed that in operating it the pipe is inserted at the back with the end to be threaded placed against the back of the dies, and there clamped by a self-centering vice. The dies are set to the required size by turning a face-plate to the graduation for the size of the pipe to be threaded. As a large die-carrying gear is revolved, a slight pressure on a lever at the top of the machine causes it to recede into the shell of the machine, and feeds the dies to the pipe. When the thread is cut the dies are thrown back, and the pipe removed without running back over the thread.

G. Flohr † has devised a method of cutting I-iron, in which the gear is provided with a single movable cutting edge. This movable cutter is placed between three pairs of fixed ones in solid frames. The face of the movable cutter has a double tooth arrangement to admit of the cut being continuous.

Metal Sawing Machines.—Illustrations have been given ‡ of two circular sawing machines, one for hot and the other for cold metals. In the machine for hot metals, the saw is of the highest quality of steel, fixed upon a steel shaft and running at 1400 revolutions per minute. It is cased in to prevent accidents, and the table which carries the bar to be cut is moved by a hand-lever either from the front or back of the machine. In the cold-metal saw, the blade is 26 inches in diameter, and cuts any thickness up to about 8 inches. Thus it will slit a heavy steel railway bar cold, or cross-cut it at any angle; it has self-acting feed motion variable for different speeds, and self-acting stop. The horizontal movement is 24 inches, but it can be made longer. This machine is made in larger sizes for sawing steel ingots, cutting the heads of steel castings and similar operations.

* Vol. I. p. 729.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 10.
‡ *Iron*, vol. lxi. pp. 112, 114.

PHYSICAL PROPERTIES.

The Crystalline Structure of Iron.—Dr. G. Linck* observes that pure iron crystallises in the cubic system, as a rule in tiny crystals with octahedral or cubic faces, or with a combination of both. They are joined together with systems of parallel axes in various directions, forming the fir-tree crystals so frequently observed in hollows in castings. When a larger mass of metal cools slowly under slag, no faces are observable, but still the cleavage of the metal as a whole is in accordance with the cubic system, and it may be considered in reality as a crystal. These general rules afford, however, but a very slight insight into the crystalline structure of iron. The views on this question are, however, capable of considerable development if there is taken into consideration the alloys of iron and nickel occurring as meteoric masses, which appear to behave in this respect as pure iron. On the Agram meteorite, which fell in 1751, Widmanstätten discovered, by polishing and rusting, the figures that have since borne his name. He found that this meteoric mass consisted of a series of layers of different thickness, and containing varying percentages of nickel. Those richer in nickel, being less soluble in nitric acid than the others, gave rise to the development of figures when the metal was etched. Baron von Reichenbach observed three different alloys of iron and nickel in meteorites, and G. Rose, taking these experiments into consideration, defined the structure of this iron with Widmanstätten figures as being due to alloys with different percentages of nickel, arranging themselves in layers the one upon the other, in accordance with the faces of the octahedra. There is, however, another kind of meteoric iron, whose classic representative is the meteorite which fell at Braunau in 1847. This forms a single crystal, with perfect cubic cleavage. The etched surfaces show pitting corresponding to embedded cubes, and in addition there are visible six systems of lines, due, in Naumann's opinion, to many cubes having grown together into a system

* *Stahl und Eisen*, vol. xiii. p. 243.

of twins in such a manner that each pair of cubes have a common diagonal passing through the centre of the cube, and that they stand inverted. The author has recently succeeded in explaining the texture of these two varieties of meteoric iron in another way, and in proving the truth of his opinions by gonimetric measurements. There are really only two iron-nickel alloys in the metal showing the Widmanstätten figures, tænite and kamacite. The former surrounds the latter, which forms crystals, each and every one of which corresponds to a more or less completely formed octahedron, one of the planes of which has a tabular development. These crystals are so grown together that they have a common octahedral face, but are twisted 180° in this plane, giving as a result a regular network of crystals, separated from each other by a thin film of the other alloy, tænite. The Naumann lines are due to thin twinned lamellæ arranged within the crystals according to the twelve pairs of faces of the rhomic dodecahedron.

The Homogeneity of Iron.—It is stated by F. L. Enquist * that in the manufacture of Uchatius steel at Vikmanshyttan in Sweden, the metal is drawn into octagonal bars having a thickness of about three-quarters of an inch. The pipe, which is formed when the ingots for these bars are cast, was rolled out with the rest of the metal, and caused the bars, in places, to become unsound. This unsound portion used to be eliminated by cutting off the ends of the bars piece by piece from the pipe end, until metal was obtained the fracture of which showed no signs of flaw. This method, however, was not only tedious, but led to a loss of metal, as portions of the bars that were free from flaws were cut off with those portions in which some trace of piping really existed. Experiments made with the magnetic needle showed, however, that this latter indicated where the end of the piped portion ceased, as it was found that when the bar was broken half an inch to either side of the spot the magnet indicated, no sign of the pipe could be discovered. Finally the magnet was solely employed for this purpose, the bar being broken at the spot decided upon. In this way lengths varying by many feet in the case of different bars could be broken off with certainty. Another important use of the magnetic needle in bars of this kind was also observed. The middle portions of some bars showed a marked disturbing action on the needle, without the exterior portion of the bar showing any sign of a want of homogeneity. When, however, such bars were broken, it was found that they were of a much coarser texture at

* *Teknisk Tidskrift*, vol. xxii. p. 275.

these points than they were elsewhere. Later on it was discovered that the half-drawn ingots were allowed to stay in the heating-furnace during the dinner-hour, the drawing-out being afterwards resumed. Bars treated in this way assumed a coarsely crystalline structure, and this the magnet indicated. The method of observation employed was a very simple one. The bars to be tested were placed horizontally in a N.—S. position, and a small pocket-compass moved along them at the side from one end of the bar to the other. The needle should then turn gradually through 180°, but where there were inequalities in the metal, not only was an alteration in this gradual movement observable, but it was frequently of a most pronounced character.

Another apparatus used for the same purpose as the needle is the Schiseophone, a combination of a microphone with a telephone and induction coils. The metal is struck at points along its length, and at spots where there is a flaw the sound observable through the telephone is different from that where the metal is free from flaws.

Microscopical Investigation of Metals.—A. Martens * describes the methods that he uses for the preparation of slides, and of simple fractures of metal for microscopic work. The foundation cement and the polishing material have to be prepared with great care. To polish the material fine emery is first used, and then the specimen is finished on glass, cast iron, copper, or lead plates, specially prepared. The polishing material is sized by washing and settling in a conical vessel, and the finest material is used mixed with ether or spirit. The specimens are about $\frac{1}{2}$ inch square, and $\frac{1}{16}$th inch thick. Several are cemented side by side, and are polished in a lens grinding machine or by hand. Colouring is advantageously used in the preparation of specimens, especially with pig iron, as the various constituents are strongly contrasted. With wrought iron, however, there is not much advantage. The author describes at some length the apparatus used at the Berlin Royal Experimental Institute for Microphotography. Several negatives are taken with different exposures, and the best is selected as a basis for future work, and similar means are adopted in developing the plates, so that the process becomes almost one of routine work.

Dr. H. C. Sorby † describes the results of his investigations on the microscopic structure of iron and steel, explaining the methods of

* *Verhandlungen des Vereins für Eisenbahnkunde*, 1892, p. 67.

† Lecture before the Derby Society of Engineers, delivered October 28, 1892; through *Industries*, vol. xiii. pp. 466–467.

preparing the sections, and of using them under oblique and direct reflection.

The Determination of the Hardness of Steel.—C. A. Caspersson * attaches a thermometer to both the normal steel and the steel under comparison, the thermometer being marked with a scale of hardness. Then a weak current of electricity is passed through the specimens, until the thermometer attached to the normal steel reaches the recognised degree of hardness; the hardness of the specimen being tested can then be read off directly from the thermometer attached to it.

The Law of Hysteresis.—Mr. C. P. Steinmetz † has recently published the second part ‡ of his lengthy investigation on the law of hysteresis and other phenomena of the magnetic circuit. To determine the loss of energy in a magnetic cycle between two limits, pulsating currents in the magnetising helix, and also the Eickmeyer differential galvanometer were used. As in the previous research, the tests were carried out on a large number of different samples of iron and steel and alloys of iron. Amongst other bodies, an amalgam of iron and mercury containing 11 per cent. of iron was tested, and although it is strongly attracted by a magnet, yet it has only twice the permeability of air. Amalgams of nickel were also found to be magnetic. The hysteresis of porous iron obtained from the amalgam, and of nickel and cobalt, are also given. The results obtained are summarised, and are given as mathematical equations, which are found to hold good for all kinds of wrought and cast iron and steel, for nickel and magnetite, and most likely for amalgam also. The investigations are then continued on iron in various states, such as coiled wire, laminated plates, and iron filings. Altogether, it appears that molecular friction in magnetisable materials, under variations of magnetisation, is much more constant a phenomenon than has been usually supposed. The question of calculating the work absorbed from the hysteresis curves is then discussed, and also the theory of molecular magnets. In the course of the paper very numerous tables of results, many of which are plotted as curves, are given.

The Electrical Testing of Iron.—Schwoller§ describes an apparatus and method for measuring hysteresis and loss in iron used for the

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxvii., p. 318.
† *Transactions of the American Institute of Electrical Engineers*, vol. ix. pp. 621-746.
‡ *Journal of the Iron and Steel Institute*, 1892, No. I., p. 464.
§ *Elektrotechnische Zeitung*, 1892, p. 353.

manufacture of transformers. The sample is cut up into strips and built up with insulation into a laminated prism. This core is placed between the poles of an electro-magnet and the induction is measured, after which the power is observed when the sample is withdrawn. The cores of the electro-magnets are also laminated. The values obtained exceed those observed by Ewing by 60 to 70 per cent.

Wrought or Cast Iron for Field Magnets.—Mr. A. D. Adams * points out some of the advantages of wrought over cast iron for the field-magnet frames of bi-polar dynamos. In good hammered scrap iron about $2\frac{1}{2}$ times as many lines of force can be produced as in good grey cast iron, by the same magnetising force as measured in ampère turns.

The weight of iron and copper for the field-magnet and winding in a machine of given capacity are therefore both more than twice as great when cast as when wrought iron is used entirely. When the field-magnet is made partly of cast and partly of wrought iron, the increase of iron and copper is not so great, and varies with the relative section of the cast and wrought iron parts. The advantages of wrought iron over cast for the field-magnets of bi-polar dynamos seem to be more generally appreciated in England than in America, as nearly all the leading makers of such machines there use forged wrought iron entirely for field-magnet frames.

Recording Apparatus for Testing-Machines.—Mr. T. Gray † describes an autographic recording apparatus for use in testing materials. It draws a double diagram of the change of length in the specimen in comparison with the stress applied during the test. One curve magnifies the change of length from 100 to 500 times as desired, and shows the behaviour below the electric limit. The other diagram shows the relation of the permanent changes of length to the forces producing them, and the scale of this curve can also be adjusted. Two frames are pivoted at their centres on the test-piece, and are connected on one side by a link, the other ends of the two levers are connected one to a cross-head of the machine and the other by a link to a vertically colliding rod. With this arrangement, slip in the jaws does not affect the device, but the vertical rod moves a distance equal to twice the extension of the test-piece. The motion of this rod is taken up by two levers. One of these

* Paper read at the St. Louis Convention.

† *Transactions of the American Society of Mechanical Engineers*, vol. xiii. pp. 633–646.

is a simple lever, which magnifies the stretch four or less times, and the other is connected to a series of levers which altogether magnify the motion from 100 to 500 times. The latter set is automatically disengaged as soon as the electric limit is passed. Each of these sets of levers works a pen over a rotating drum. Several of the curves drawn by this device are shown.

The Testing of Iron and Steel.—Mr. T. Morris* considers engineers' tests of iron and steel from an ironmaster's point of view. A large number of engineers' specifications are tabulated, and their requirements discussed. The elastic limit test is condemned, and reference is made to tensile tests with and across the grain, and to the effect of the length of the test-piece on the elongation. A large number of examples are given to illustrate this, the average being as follows:—

Length of test-piece, inches . . .	9⅞	6½	3½
Elongation per cent., average . .	6·5	7·0	8·5

To a certain extent there is also a variation in the tensile strength found by taking different lengths of test-pieces. The effect of grain on the strength may be lessened by cross-filing, but there is danger of including slag or cinder. The elastic limit may be the same in very different kinds of iron, as is shown by some results obtained by Mr. B. Marshall:—

Description.	Tensile Strength.	Reduction of Area.	Elongation in 10 Inches.	Limit of Elasticity.
	Tons per Square Inch.	Per Cent.	Per Cent.	Tons.
½-inch plate rolled from puddled bar	18·8	5	4	16·0†
	22·6	15	12	15·5‡
½-plate rolled from ingot iron . .	32·2	24	8	15·7†
½-inch puddled iron plate . . .	18·6	4·5	3	13·8
1½-inch Bowling round bar . .	22·7	55	29	13·7

The reduction of area as a test for ductility is well worthy of consideration, as it can generally be easily obtained, whilst the specifications for elongation tests are most confusing. The following standard tests are recommended, no conditions lower than those given being allowed:—

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, February 4, 1893.

† Across grain.

‡ With grain.

Quality.	Tensile Strength.	Reduction of Area.
	Tons per Square Inch.	Per Cent.
Best rounds and squares	22·5	20·0
Best flats	22·0	15·0
Best angles and tees	21·5	12·5
Best plates, with grain	21·0	8·0
Best plates, across grain	17·0	4·0
Best best rounds and squares	23·5	30·0
Best best flats	23·0	20·0
Best best angles and tees	22·0	17·5
Best best plates, with grain	22·0	10·0
Best best plates, across grain	18·0	5·0

Bars.—If the tensile strength falls short of the specified test, and the reduction of area (or elongation) is correspondingly high, the iron to be deemed satisfactory. The same course may be taken in the case of high tensile strength and low reduction.

Plates.—If the tensile strengths with and across the grain are equal in the aggregate to the sum of the above specified tests, the iron shall be deemed satisfactory. The same is to apply to the reduction of area with and across the grain. Two test specifications are given under the names of "best" and "best best" as most structures of late years have been built of these materials.

The joint German Commission has decided * that in testing a material tensile, bending, and working tests are to be made. The test-pieces are to be taken from cold metal and to be worked up cold, and they must not be annealed unless the metal being tested had been so annealed, and the skin produced on the metal during the rolling is to be left as intact as possible. The test-pieces shall have a test length of 7·89 inches, and an area of from 0·31 to 0·77 square inch. In the case of round test-pieces less than 0·79 inch in diameter, the test length is to be ten times the diameter. Above and below the test part proper the bars are to have the same sectional area for a length of 0·39 inch. The test is to be repeated should the fracture occur within the middle third of the test part, if the elongation is unsatisfactory. For the bending tests metal strips 1·18 to 1·97 inch broad, or round bars are to be employed. There should be no sharp edges.

As regards the quality of the material, the requirements hitherto accepted for weld iron remain practically unchanged. In the case of ingot metal the surface should be regular and without flaws or cracks at the

* *Stahl und Eisen*, vol. xii. pp. 950–953.

edges. One sample only to be taken for every ton of metal tested. If the test is unsatisfactory two other test-pieces are to be tried, and if one of these gives similar unsatisfactory results, the metal is to be rejected.

For metal from 0·28 to 1·10 inch in thickness, the following regulations are to hold good, but for metal of other thickness special test regulations are to be mutually agreed upon:—Longitudinally the tensile strength shall not be less than 23·5 nor more than 27·9 tons per square inch, with an elongation of at least 20 per cent. Across the fibre or grain the tenacity must be at least 22·9, but must not exceed 28·6 tons per square inch, while the elongation must not be less than 17 per cent. For screws and rivets the tensile strength may vary from 22·9 to 26·7 tons per square inch; the elongation must be at least 22 per cent.

With regard to bending tests, the metal should be heated to redness, and then plunged into water having a temperature of about 28° C. It must then be bent round a curve, whose diameter at the bending point is equal, in the case of longitudinally taken test-pieces, to the thickness of the test-piece, and for test-pieces taken across the metal, to double the thickness of the test-piece. In the case of the longitudinal test-pieces no cracks must show, but in the case of the others surface cracks of little importance are permissible. With regard to the tests made at a red heat, punching tests must be made, and a 0·79 inch hole so punched must be widened out to a diameter of 1·18 inch. For rivet or screw metal the test-piece must be bent to an angle one half the thickness of the test-piece without showing cracks, and it must be capable of being hammered down to a third of its length without cracking. Similar tests are also described for rivet and screw metal, for ingot steel, and for steel castings.

Mr. J. Sondericker* gives a description of some repeated stress experiments. Failure under repeated stress may occur from some molecular change set up in the mass, or may be the outcome of a gradually extending crack. During a year and a half the author has been experimenting with a view to studying the elastic changes produced by such stresses. A test-shaft loaded at points equidistant from the bearings was caused to revolve 500 times per minute until it cracked. At intervals the shaft was stopped and measurements taken with and without the load. Sixteen specimens have been tested, including wrought iron, open-hearth and Bessemer steel, and cold-rolled shafting. The test-bars

* *Technology Quarterly*, vol. v. pp. 70–80.

were one inch in diameter. In each case the changes are rapid at first, and then proceed more slowly until the bar settles into a stable elastic condition. Steel appears to behave differently to iron, and the elastic limit does not appear to be a sufficient criterion for judging the capacity of the material to resist repeated stress. In two cases the metal stood stresses beyond the elastic limit; in the third, elastic changes tending to increase the set have occurred far within this point, and a large proportion of the test-bars broke within the elastic limit without any elastic changes occurring. No direct connection has been established, but the results may be of use in discussing the effects of repeated stresses. The positions of the fractures and curves showing particulars of the experiments are given.

Testing Cast Iron.—An account is given by Mr. W. J. Keep * of his method of testing cast iron, with a large number of illustrations to show the apparatus employed and the methods of using it. Amongst the various matters dealt with are the size of the test-bars, moulding, casting, preparing and measuring them, and determining the shrinkage. The dead-load testing machine is described, and the method of using it is fully set out. The determination of the depth of chill and kind of grain is also described. Testing for fluidity and distorsion due to shrinkage in a bar of T-section are mentioned, and then the machine for measuring the strength under impact is described. The results obtained by submitting the test-piece to a dead-load and to impact are compared, an arbitrary table being given for this purpose. The machine for testing the hardness of the iron is also described. Some illustrations of fractures of various irons are also appended to show the effect of varying the mixture used.

The Properties of Steel.—Professor J. W. Langley † observes that steel may be defined as iron holding in solution, in whole or in part, other elements within certain regulated limits, cast iron and ferro-silicon being excluded. The elements, which steel must contain to fulfil practical requirements, are carbon and silicon, but some fifteen other elements may also be present. The following table shows the approximate quantities of the more important elements occurring in steel:—

* *American Machinist*, 1893, Nos. 1, 2, 3, and 6.

† *Transactions of the American Society of Civil Engineers*, vol. xxvii. pp. 385–405.

Elements.	Commercial Steels.		Alloy Steels.	
	Upper Limit.	Lower Limit.	Upper Limit.	Lower Limit.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	1·50	0·30	2·25	1·25
Silicon	0·30	0·02	1·50	0·50
Sulphur	0·10	0·005	0·10	0·005
Phosphorus	0·10	0·01	0·30	0·01
Manganese	1·00	0·08	15·00	5·00
Tungsten	...	...	7·00	0·50
Chromium	...	...	2·00	0·25
Oxygen	0·20?	traces	2·00	0·25
Hydrogen and nitrogen	very little	very little	2·00	0·25

The lower limit indicates those quantities of the elements at which their specific action ceases to be sufficient to give the "alloy steel" special properties.

The lower limit of carbon in commercial steel is given at 0·30, because below this the metal becomes incapable of any notable amount of hardening when suddenly cooled.

The upper limit for oxygen is queried, because there are no wholly satisfactory methods of analysis for this element in the presence of large quantities of iron.

Hydrogen and nitrogen have been found in small quantities in all steels. Carbonic oxide appears likewise to be a universal ingredient of steel.

The author considers that steel really represents merely a solution of certain bodies in iron, and this, too, whether the steel be molten or solid. It is known that all compounds, when in solution, tend to dissociate, and it would seem, therefore, that if definite carbides, oxides, or phosphides were introduced into molten iron they would to a certain extent, at any rate, become dissociated.

The author next proceeds to consider the influence of various elements on iron. Oxygen, he observes, may be dissolved in iron, and its influence is very deleterious. The influence of carbon, both alone and in conjunction with other elements, is also considered, and the question of chilling is dealt with at some length.

The author gives what he terms "equations of annealing" and of "chilling." These are as follows, the chemical composition of the iron forming the basis of the equations:—

$$\text{Tendency to chill} = \frac{C \times Mn}{Si} \times \frac{1}{t}.$$

$$\text{Power of annealing} = \frac{Si}{C \times Mn} t.$$

The one is therefore the inverse of the other. The influence exerted by manganese is complicated. That of carbon, and to some extent also of silicon, is shown in the following table :—

No.	Carbon.	Ultimate Strength.
	Per Cent.	Lbs. per Square Inch.
1	Under 0·30	58,760
2	0·50	87,726
3	0·70	87,975
4	0·70	108,095
5	Under 0·30	63,790
6	Under 0·30	73,887
7	0·35	76,952
8	0·62	84,500
9	0·22	86,450

In Nos. 1 to 7 the silicon was about 0·20 per cent.; phosphorus, under 0·05; sulphur, under 0·03. Nos. 8 and 9 contained less than 0·03 silicon, but they carried some tungsten, and therefore belonged to the group of special steels. The last one especially shows that tungsten increases the tensile strength of mild steel, but the increased difficulty of working it largely neutralises its benefits.

Tungsten, the author observes, is usually believed to make iron hard. This belief, however, is entirely erroneous, for if the steel be not exceedingly high in carbon and manganese, as, indeed, all self-hardening specimens are, then no percentage of tungsten will make the steel file hard if it be allowed to cool slowly in air. The true action of tungsten appears to be to delay the rate of change of state of the carbon also present in the metal. The author compares its action to that of glue in water in delaying the action of the water either in dissolving a salt or in allowing the salt to subsequently crystallise out. By the use of an emery wheel less than 0·5 per cent. of tungsten can be detected in a steel, as it will give only a dull fire, free from exploding sparks, instead of the brilliant shower of sparks that usually forms. Chromium, like manganese, is a true hardener of iron, even in the absence of carbon. As in the case of manganese, it, too, helps to keep the carbon in solution, though much less powerfully.

The author next proceeds to consider the action of sudden cooling on the grain and hardness of the metal. With reference to the specific gravity of the metal, he shows that this decreases with an increase in the temperature at which the cooling was effected. Rolling increases the density of steel, and a decrease in the specific gravity follows an increase in the percentage of the carbon. The author also passes in review the

question of recalescence and of the changes in condition of the various elements in the iron by which the recalescence is accompanied.

In a subsequent communication Professor J. W. Langley * discusses some of the physical properties of steel as related by its structure and composition. Steel is defined as a solution of several elements, such as carbon, phosphorus, silicon, and manganese, in iron. Limitations of this definition for high steels are given. Combination and solution are explained, and reasons are shown for considering steel as representing the latter rather than the former. The influence of the four elements mentioned above on the fusibility, hardness, and toughness are given by a set of curves showing the relation between these properties and the amounts of included elements. Hardening and annealing, together with the phenomena of recalescence, are also discussed.

Professor J. W. Langley † also discusses some of the mechanical properties of high steel as related to its composition and structure. The effect of a quantity of any of the elements carbon, silicon, phosphorus, sulphur, and manganese on any particular mechanical property of the metal when plotted gives a curve which has a general resemblance to a parabola, and all tend, with perhaps the exception of the manganese hardness curve, to become asymptotes to one axis. Some of the curves that show this are given.

The Chemical and Physical Relations of Steel.—As the result of the investigation of 500 samples of universal and sheared plates of basic Bessemer and basic open-hearth steel, Mr. W. R. Webster ‡ has tabulated his observations on the relations between the chemical constitution and the physical character of steel. The first table shows the estimated ultimate strength in lbs. per square inch for steel containing 0·07 to 0·17 per cent. of carbon, 0·005 to 0·1 per cent. of phosphorus, and no manganese. An abstract of this table is as follows :—

Carbon =	0·07.	0·09.	0·11.	0·13.	0·15.	0·17.
Phosphorus.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0·01	44,400	46,100	47,900	49,700	51,500	53,100
0·03	46,000	47,900	50,100	52,300	54,500	56,100
0·05	47,600	49,700	52,300	54,900	57,500	59,100
0·07	49,200	51,500	54,500	57,500	60,500	62,100
0·09	50,800	53,300	56,700	60,100	63,500	65,100
0·10	51,600	54,200	57,800	61,400	65,000	66,600
0·01 P =	80	90	110	130	150	150

* Paper read before the Civil Engineers' Club of Cleveland.

† *The Sibley Journal of Engineering*, vol. vii. pp. 119–124.

‡ *Transactions of the American Society of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

The indications are that a pure iron, without carbon, phosphorus, silicon, or manganese, would give 38,000 lbs. ultimate strength. This is assumed as a basis, and the effect of each element given above is added. In basic open-hearth steel, about 21,000 lbs. should be deducted from the addition for manganese. Carbon is credited with a constant effect of 800 lbs. for each 0·01 per cent. Phosphorus has a greater effect in high than in low carbon steels. For 0·07 to 0·08 carbon it has about the same effect as carbon—that is, 800 lbs. for each 0·01 per cent. of phosphorus. The effect of phosphorus is as shown below :—

For Carbon.	Increase of Ultimate Strength per 0·01 per Cent. Phosphorus Added.	Effect of Unit of Phosphorus to Unit of Carbon.
Per Cent.	Lbs.	[As 1 to
0·09	900	$1\frac{1}{8}$
0·11	1,100	$1\frac{3}{8}$
0·13	1,300	$1\frac{5}{8}$
0·15	1,500	$1\frac{7}{8}$
0·17	1,500	$1\frac{7}{8}$

The effect of manganese seems to decrease as its percentage increases, but it may be necessary to take both carbon and phosphorus into account. Provisionally the following is given :—

Manganese.	Increase of Ultimate Strength.	Total Increase in Ultimate Strength from 0·0 Manganese.
Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
From 0·0 to 0·15	3,600	3,600
,, 0·15 ,, 0·20	1,200	4,800
,, 0·20 ,, 0·25	1,100	5,900
,, 0·35 ,, 0·40	800	8,600
,, 0·45 ,, 0·50	600	9,900
,, 0·60 ,, 0·65	500	11,400

As there is only a trace of silicon in this steel, it has not been considered. With other steels, its effects might be grouped with some of the other elements in such a way that by the use of two tables the results of all the four hardeners might be obtained. The action of sulphur has not been investigated.

Of the 500 tests mentioned above, 80 per cent. worked out by these tables came within 5000 lbs. of the actual strength, without allowing for the width and thickness of the plates. When applied to analyses and strengths for acid steel given by Mr. Salom, the results were almost

uniformly 2000 lbs. too high, and 94 per cent. were within 5000 lbs. To allow for variation in the size of the plates from which the tests are taken, the following table is given, compiled from the results given by the author:—

Thickness.	Under 70 Inches.	70 to 85 Inches.	Over 85 Inches.
Inch.	Lbs.	Lbs.	Lbs.
1	-5000	-4000	-3000
⅞	-4000	-3000	-2000
¾	-3000	-2000	-1000
⅝	-2000	-1000	...
½	-1000	...	+1000
⅜	...	+1000	+2000
¼	+2000	+3000	+4000

The results of these investigations are also given in a graphic form.

Endurance of Tempered Steel.—Mr. W. A. Doble* of San Francisco has published the results of a series of experiments to ascertain the effect of blows systematically given on the ends of sections of steel bars, set in an anvil or heavy casting, the sledges being swung by men striking in time and with full force. The third column relates to a degree of temper at present adopted by the A. Doble Company as that of highest resistance, and which is not easy to define, further than it is a mean between the malleable and friable state of the steel, and belongs to what is technically called "blue tempers." The scheme of such trials was suggested by the former rapid destruction of various implements made by the Company, such as wedges, drifts, drills, chisels, and so on, due to their being frayed, split, and upset at the top, also to determine the effect upon hammers and sledges as the implements struck were increased in hardness.

Description.	Steel Forged, not Tempered.	Mild Temper.	Standard Temper of Doble Co.
Size of test-plug	1½ in. sq.	1½ in. sq.	1½ in. sq.
Duration of test in hours	1	4	4
Number of sledges	3	3	3
Weight of sledges	10 lbs.	12 lbs.	12 lbs.
Number of blows	5,000	19,000	19,000
Original length, inches	$5\frac{15}{32}$	$5\frac{7}{32}$	$5\frac{31}{64}$
Present length, inches	$5\frac{7}{32}$	$5\frac{3}{32}$	$5\frac{15}{64}$
Reduction in length, inches	$\frac{8}{32}$	$\frac{4}{32}$	$\frac{1}{64}$

* *Iron Age*, vol. l. p. 1160.

Remarks.—Steel forged, not tempered, head spread to average, $2\frac{1}{8}$ round. Mild temper, head spread to average, $1\frac{7}{8}$ round. Standard temper of the A. Doble Company head did not spread; apparently as good as before tested. The faces of the striking sledges were polished and the grinding marks were not obliterated. The sledges were used about seven hours each. These pieces were forged from $1\frac{1}{2}$ inch square steel, but the heads were swaged to $1\frac{1}{2}$ inch round, which reduced the area subject to the force of the blows.

The Uses of Steel.—A. Semlitsch* tabulates the uses of open-hearth steel and ingot metal, in respect to the hardness of the material. His table shows:—

Tensile Strength.	Reduction of Area.	Elongation.	Use.
Kilog. per sq. mm.	Per Cent.	Per Cent.	
60 to 96	33 to 5	10 to 4	Files.
60 ,, 71	33 ,, 29	10 ,, 4	Tools.
48 ,, 59	45 ,, 34	25 ,, 10	Beams.
48 ,, 54	45 ,, 40	25 ,, 20	Axles.
Under 47	over 60 ,, 45	over 30 ,, 25	Rivets, spades, hoes, &c.

The very softest metal can alone be used in the manufacture of horse-shoe nails. All the harder kinds of metal must be free from blowholes, but this danger is of less importance in the case of the softer grades of metal. The author mentions a number of other uses to which the various grades of steel can be put.

The Selection and Treatment of Steel for Forgings.—According to Mr. F. Rixsom Rixon† the steel best adapted for forgings such as piston-rods, shafts, and cranks which are subject to severe torsional strains, together with heavy loads, should have a tensile strength of 27 to 30 tons, high elongation, 35 per cent. on 2 inches, and 45 to 55 per cent. reduction of area. A bending test-piece, 1 inch square and 10 inches long, should bend round a rod $1\frac{1}{4}$-inch in diameter to V-form without signs of failure. For high-speed engine-cranks, the steel should have a tensile strength of 34 tons, with 28 per cent. elongation, and 52 per cent. reduction of area. In the author's opinion, 0·30 per cent. of carbon is preferable, as the harder metal stands a punishment or fatigue test best. With regard to the treatment, it is essential that heating be

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 2.

† Paper read before the Leeds Association of Engineers.

done slowly and uniformly. Hammering should be done with care, and not at all in the cold, as it promotes brittleness. No complete remedy has been found for bubbles or flaws. Forging to shape by the hydraulic press, and tempering, are referred to.

Boiler Plate.—At the November Meeting of the American Society of Mechanical Engineers, Mr. F. H. Daniels* described a boiler explosion in which one of the plates in the third row, just over the most intense heat, "bagged" and ruptured, leaving an orifice about 1 inch in diameter, in which the metal around the orifice had thinned to a knife edge. Analysis showed the plate to contain:—

Phosphorus.	Sulphur.	Silicon.	Manganese.	Carbon.
0·063	0·022	0·024	0·261	0·100

This plate, when originally tested, was found to possess a tensile strength at one end of 68,050 lbs. per square inch, and at the other end of 65,550 lbs. After rupture, the tensile strength of the plate in the immediate vicinity of the bulge was 61,666 lbs. per square inch, with a reduction of area of over 32 per cent., and at the part of the plate farthest from the bulge 60,486 lbs., with a reduction of area of 41 per cent. These test-pieces were, however, not perfectly straight ones, owing to the bulge.

Mr. A. J. Dubston† has made a large number of experiments on the transmission of heat through plates in connection with the tube-plates of boilers. Some note is also taken of the material employed for the tubes.

Maryland Rail Steel.—Details are published‡ which relate to a number of blows made by the Maryland Steel Company, United States. The carbon contents of the metal treated varied between 0·34 and 0·40. The following are analyses of the metal made:—

Heats.	Silicon.	Phosphorus.	Manganese.	Carbon.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
12,106-12,122	0·000	0·085	1·00	...	0·030
12,123-12,143	0·056	0·073	1·07	0·408	0·043
12,144-12,164	0·052	0·082	1·03	...	0·051
12,165-12,185	0·060	0·085	0·96	0·396	0·089
12,186-12,204	0·028	0·081	0·93	...	0·066

* *Iron Age*, vol. l. p. 1084.

† Paper read before the Institution of Naval Architects, March 22, 1893.

‡ *Iron Age*, vol. li. p. 670.

The metal was rolled into rails, and test-pieces were cut from the rail web. These were then submitted to mechanical tests, with the following results :—

No.	Elastic Limit.	Tensile Strength.	Elongation on 8 Inches.	Reduction of Area.	Elongation on 2 Inches.
	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Per Cent.	Per Cent.	Per Cent.
I.	62,100	100,400	15·50	24·61	25·00
II.	58,540	91,530	14·50	25·95	23·00
III.	54,310	90,540	16·50	20·81	24·00
IV.	53,190	90,820	18·00	26·00	25·00
V.	60,200	93,720	14·25	30·70	25·00
VI.	55,700	92,120	16·50	27·90	26·00

The elongation on 8 inches was calculated from that observed on the smaller length.

The drop-test gave the results shown in the following table, the distance between bearings being three feet, and the weight of the tup one ton.

Carbon.	Fall of Drop.	Deflections.		
		After First Blow (on Head).	After Second Blow (on Head).	By Third Blow (on Flange).
Per Cent.	Feet.	Inches.	Inches.	Inches.
0·036	10	$2\frac{1}{2}$	$4\frac{3}{8}$	$2\frac{3}{8}$
0·039	10	$2\frac{1}{2}$	$4\frac{3}{8}$	Piece turned.
0·038	10	$2\frac{5}{8}$	$5\frac{1}{4}$	3
0·039	10	$2\frac{3}{4}$	5	3
0·038	10	$2\frac{3}{8}$	$4\frac{3}{8}$	$2\frac{3}{8}$
0·039	10	$2\frac{3}{4}$	$4\frac{3}{4}$	3
0·037	20	$4\frac{7}{8}$	$8\frac{1}{4}$	$5\frac{1}{4}$
0·037	20	$4\frac{1}{4}$	$8\frac{3}{8}$	Piece slipped.
0·039	20	$4\frac{1}{16}$	$8\frac{1}{4}$	$5\frac{3}{8}$
0·038	20	$4\frac{1}{8}$	$8\frac{1}{2}$	Piece slipped.

The quality of the metal, it will be seen, was very good. It may be pointed out that the percentage of manganese it contained was somewhat high.

Steel and Iron for Rolling Stock.—The advantages of steel and iron are compared by Mr. G. Richards, and the subject has been discussed at some length by the New England Railway Club,* especially with regard to the axles. Uniformity in the quality of the product is

* January 11, 1893.

one feature that is especially desirable, as breakages of wheels or axles can generally be traced to inferior material, faulty manipulation, or bad design. Steel axles are often condemned because the broken ones show a less mileage than broken iron axles, but it is found that steel axles have a much longer life than iron ones when both are sound.

An account of the fracture of railway tires on the German State railways from 1884 to 1890 is given by Bork.* The fractures averaged 0·28 per cent. of the wheels used in these seven years. In locomotive wheels the fractures were 0·5 per cent., in tender wheels 0·65, and in passenger vehicles 0·38 per cent. The fractures largely depended on the thickness, as shown below :—

Thickness in inches	Over 2·362	1·968 to 2·362	1·575 to 1·968	1·378 to 1·575	1·181 to 1·378	0·984 to 1·181	0·787 to 0·984
Fractures per cent.	0·025	0·08	0·29	0·54	1·05	1·65	1·85

Much information is given in the course of a series of articles on the construction of the modern locomotive † about the use of steel castings for that work. At the present time there is much difference of opinion among engineers as to the tests required and the specifications for the materials. A number of tables given show analyses of steel and the results of various tests on different steels, with the effect of annealing and other treatment. The manufacture of forgings is also dealt with at some length, especial attention being paid to the manufacture of tires and cranks.

Locks and Safes.—In describing the construction of locks and safes, Mr. H. W. Chubb ‡ gives a short and interesting history of these articles, and illustrates the various artistic and useful forms that they have assumed. In dealing with safes, some account of the metal used is given. In American burglar-proof safes, several thicknesses of steel of different degrees of hardness are used, and all joints are closed or covered with forged bands. To give extreme hardness, metal similar to spiegeleisen and capable of being chilled is sometimes run in between the inner and outer plates. In England compound plates made by rolling ingots with alternate hard and soft layers are often employed, five layers often being used. Safemakers look with considerable interest on the experiments of metallurgists in the production of steel alloys so as to obtain a perfectly

* *Verhandlungen des Vereins für Eisenbahnkunde*, 1892, p. 48.
† *The Engineer*, vol. lxxiv. p. 25-28, &c., vol. lxxv. pp. 157, 158, &c.
‡ *Journal of the Society of Arts*, vol. xli. pp. 510-528.

homogeneous plate, having the two properties of hardness and toughness sufficiently developed for their purposes.

Internal Strains in Winding Ropes.—In the course of a long mathematical investigation as to the strains which may be brought about in winding ropes and other prismatic bodies by static and dynamic stresses, H. Undeutsch * points out that for the shorter lengths of rope the tension may develop to so great an extent that the strains may even exceed the limit of elasticity of the metal. In the smaller lengths of rope, even with ordinary favourable conditions, these strains may bring about a change in the material, induce brittleness, and even lead to an actual and immediate rupture. The theory therefore agrees with the statistics resulting from actual practice in showing that the longitudinal vibrations extending in the line of the axis of the rope are causes leading to the limit of elasticity being exceeded, or to the rope becoming brittle, and those parts of a rope which are most injuriously affected by these vibrations are in the first place the lowest portion, and in the second the upper portion near the drum.

The Use of Ingot Metal.—In a paper read before the German Association of Iron Metallurgists, Mr. Kintzlé † described the results of the investigation instituted by the joint Commission appointed to examine into the question by the Association above referred to, and that of the German Engineers and of the German Architects and Engineers. This Commission, decided in the first instance, to consider the question as to the exact requirements necessary in the fulfilment of orders relating to material for bridge and other similar construction purposes. The author shows from experimental results that in one and the same material the elongation diminishes with the diameter of the test-piece, although the ultimate tensile strength is not affected, or, as it has been expressed by Martens: Geometrically similar bodies of similar material receive, under identical conditions, similar changes of form by the exertion of equal stresses. The actual shape of the section appears to have little influence on the results, whether as regards tensile strength or elongation. For every ton of metal of the same shape there need not be more than one test-piece. Rolling exerts an enormous influence on the results of the mechanical tests of the metal. As a rule, the tensile

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 565–569, 583–587, 592–597, 604–609, with two sheets of illustrations.

† *Stahl und Eisen*, vol. xii. pp. 935–950.

strength is increased and the elongation diminished. This diminution or increase in the elongation amounts to about 1·5 to 2·0 per cent. for every increase or diminution of 0·63 ton per square inch in tenacity. With a material of 27·9 tons an elongation of 20 per cent. is permissible. As to the tests across the fibre, the results of some hundreds of tests of girders and of the products of universal mills, it was found that with a material showing a tensile strength lengthwise of from 23·5 to 27·9 tons per square inch, and an elongation of 20 per cent., the same result could not be guaranteed in a test across the grain by as great a difference as 27 per cent. in the case of universal iron, and of 12 per cent. in that of sheets. Even with the requirement in a longitudinal test of 22·9 to 28·6 tons tenacity and 17 per cent. elongation, an allowance of at least about 10 per cent. has to be made in the case of universal iron, and of 4 per cent. in that of sheets. For rivets and screws the Commission considered that metal most suitable which had a tensile strength of from 22·9 to 26·7 tons per square inch and a minimum elongation of 22 per cent. In the large majority of cases there should be a permissible variation of 4 tons in the tenacity, and it must be always remembered that the elongation demanded must of necessity depend on the shape and dimensions of the test-piece to be employed. The Commission decided for steel castings on a tenacity of from 28·6 to 38·1 tons, accompanied by an elongation of at least 10 per cent. The author then refers to the use of soft basic metal for ship construction, pointing out that the requirements of the German Lloyds appear to date from a time when acid open-hearth metal was the softest material known.

Tests of Ingot Metal for the Fordon Bridge.—The results of the tests made of the ingot metal to be used in the construction of the Fordon Bridge are given by Mehrtens.* Up to January 1, 1893, there had been 700 sample tests of basic Bessemer metal, and 508 of open-hearth metal, representing in all about 10,000 tons. Of these, sixteen of the open-hearth tests proved unsatisfactory, but not a single delivery of the basic metal had to be refused. In seven cases the open-hearth metal was too hard, in five the tensile strength was too low, in two slag had been rolled into the metal, and in one instance the metal was too full of blowholes.

The tests of basic Bessemer metal showed :—

* *Stahl und Eisen*, vol. xiii. pp. 275–279. See also *Journal of the Iron and Steel Institute*, 1892, No. II., p. 495.

Material.	Limit of Elasticity.	Tensile Strength.	Elongation.
I. 680 lots of shaped iron :—	Tons per Sq. In.	Tons per Sq. In.	Per Cent.
Lower limit	15·81	24·82	21·0
Upper limit	20·70	27·81	32·5
II. 20 of rivet iron :—			
Lower limit	16·51	24·06	25·2
Upper limit	18·16	25·08	29·8

The analyses which were made showed that the percentage of phosphorus varied from 0·019 to 0·099, that of manganese from 0·25 to 0·88, and of sulphur from 0·017 to 0·071, while the percentage of silicon did not exceed 0·010, nor the percentage of carbon 0·10. In only one of the 700 did the phosphorus exceed 0·09, and the manganese in one other 0·8, while only in three cases did the sulphur exceed 0·06.

The open-hearth metal showed the following results when submitted to mechanical tests :—

Material.	Limit of Elasticity.	Tensile Strength.	Elongation.
I. 429 lots of shaped iron :—	Tons per Sq. In.	Tons per Sq. In.	Per Cent.
Lower limit	15·24	24·76	20·0
Upper limit	22·73	29·84	37·5
II. 19 of rivet iron :—			
Lower limit	14·98	23·05	25·0
Upper limit	19·49	25·40	35·0

In 508 lots of open-hearth metal the percentage of phosphorus varied between 0·03 and 0·08, and that of carbon from 0·09 to 0·14. In eighty-four lots analysed for manganese, the percentage of this element contained in the metal was found to vary between 0·34 and 0·66, while in sixty-seven cases sulphur was present in quantities varying from 0·04 to 0·12 per cent.

According to Mr. Weyrich* the ingot metal to be used in the construction of the Fordon Bridge, Germany, was required by the terms of the contract to contain as maximum percentages :—

C.	P.	Mn.	Si.	S.
0·10	0·05	0·35	0·02	0·02

The physical tests were required to show a tensile strength of 28·6 tons per square inch, a limit of elasticity of at least 16·5 tons per square inch,

* *Stahl und Eisen*, vol. xiii. p. 82.

and an elongation of at least 25 per cent., combined with a reduction of area of not less than 50 per cent.

Basic Bessemer Steel Joists.—Some tests have recently been made * by direct loading to ascertain the strength of some basic Bessemer steel joists. The particulars are as follows:—

Scantlings.	Web.	Span.	Material.		Load Distribution on Failure.	Strain in Flanges at Failure.
			Tensile Strength.	Elongation on 8 Inches.		
Inches.	Inch.	Feet.	Tons.	Per Cent.	Tons.	Tons.
12×6×$\frac{3}{4}$	$\frac{5}{16}$	15	29·6	25·5	50	21
10×6×$\frac{3}{4}$	$\frac{1}{2}$	15	27·7	24·0	34½	21

Manganese Steel.—Mr. H. M. Howe † again refers to the researches of Tetskichi Mukai on manganese steel, giving the analysis of the steels examined by him, with some further calculations from his data on the composition of the mother mass. The effects of sudden cooling on manganese and on carbon steel are tabulated as follows:—

Property.	Effect of Sudden Cooling.		Effects in the Two Steels.
	In Case of Carbon Steel.	In Case of Manganese Steel.	
Hardness	Increase, enormous	Increase, slight if any	Like
Percentage of the total carbon in the hardening state	Increase, very great	Increase, moderate ‡	Like
Density	Decrease	In one case, increase ,, nil	Opposite
Size of grain	Nil, or decrease	Increase	Opposite
Separation of components	Decrease	Increase	Opposite
Ductility	Decrease, enormous	Increase, enormous	Opposite
Tensile strength	Increase	Increase	Like

Manganese steel, whether cooled quickly or slowly, appears to consist of a mother mass and a carbide, with an approximate composition, $Fe_{10}Mn_3C_5$. In the quenched steel there is more of the mother mass, which also contains more carbon. The slight variation in the amount of the two constituents can hardly account for the increase of ductility, and the increase of combined carbon in the mother mass acts in a directly

* *Engineering*, vol. lv. p. 653.

† *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

‡ Moderate, compared with the increase in the case of carbon steel.

opposite way to the hardening carbon in ordinary steel. The transfer of carbon in the Hörde steel was less than in the Hadfield steel, while the ductility and density was altered to a greater degree. These two factors then do not appear to be cause and effect, and there must be other causes for the results produced by quenching which mask those produced by carbon. Osmond has found that manganese lowers the range of temperature required for changing carbon into the hardening state, and if sudden cooling does not allow time for those changes, it might be expected that increase of manganese would lower the temperature required for quenching to toughen manganese steel. Apparently, however, manganese steel has to be quenched from even higher temperatures than that required for hardening steel, and this fact, though it has not absolutely been determined by experiment, tends to disprove the theory that toughening is due to the state of the carbon.

Nickel-Steel.—M. J. Garnier* gives the results of a number of tests made at the works of the Cleveland Rolling Mill Company, with a view to determine the relative quality of ordinary steel and of similar metal containing nickel. The results are given in the following table :—

Charge.	Size (8-Inch Specimen).	Section.	Elongation.	Elastic Limit.	Tensile Strength.	Remarks.
	Inches.	Square Inch.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	
Nickel-steel—						
Scrap, 9000 lbs.	1·602 × 0·300	0·4806	23¼	...	64,080	Not annealed.
Pig iron, 9000 lbs.	1·645 × 0·245	0·403	26	47,100	66,370	...
Ferro-manganese, 165 lbs. . . .	1·605 × 0·302	0·4847	25	44,700	66,000	...
Nickel, 540 lbs. .	1·582 × 0·245	0·3875	24½	47,400	67,100	...
	1·495 × 0·310	0·483	26	47,300	64,890	Annealed.
	1·495 × 0·310	0·483	23¾	48,200	66,200	...
Ordinary steel—						
Scrap, 9000 lbs.	1·545 × 0·245	0·3785	26	35,700	55,500	Not annealed.
Pig iron, 9000 lbs.	1·666 × 0·245	0·408	26	35,500	54,600	...
Ferro-manganese, 160 lbs. . . .	1·670 × 0·292	0·4876	27½	32,800	53,900	...
	1·640 × 0·290	0·4756	32	34,060	52,500	...
	1·500 × 0·303	0·454	27	35,500	53,700	Annealed.
	1·480 × 0·305	0·451	26	37,900	56,500	...

These results show that the nickel-steel possesses a much higher limit of elasticity than does the ordinary steel, the mean increase being nearly 31 per cent. The tensile strength is also greater by about 20 per cent., and there is no appreciable diminution in ductility. Analyses are not given.

* *Génie Civil*, through *Iron Age*, vol. li. p. 126.

The United States Government has decided to test the use of nickel-steel in the manufacture of machinery. To this end a section of the propeller shafting of the *Brooklyn* is to be made of nickel-steel, and the United States sea-going battleship No. 1 is to be similarly provided with such shafting.*

Tests of Armour Steel and Armour Plates.—The specifications for the armour of the new United States battleships state that the steel must contain 3½ per cent. of nickel. The weight of the ingot must be at least double that of the finished plate, and in no case must the mean cross-section of the ingot be allowed to fall during preliminary treatment to less than three times the width of the finished plate. At least 30 per cent. of the weight of the ingot is to be discarded from its upper end if the ingot has been cast in the ordinary way, or 5 per cent. if fluid compressed ingots are used in the manufacture of hollow armour forgings. In physical tests the tensile strength of plates to be Harveyised must be at least 65,000 lbs. to the square inch, with 12 per cent. elongation. For plates not intended for the Harvey process, but which are to be oil-hardened and annealed, each specimen shall show not less than 75,000 lbs. per square inch tensile strength, and 10 per cent. elongation. Four test-specimens are to be taken from each plate after forging or rolling, and before any further treatment except annealing: one longitudinal and one transverse specimen from each end of the plate. The ballistic test is considered the one of greatest importance, and the method of performing this is discussed. The Government requires that there shall be no crack extending from the point of impact to an edge of the plate, and at the same time through the entire thickness of the plate, at an edge, and neither the projectile itself, nor any part of it, shall pass entirely through the plate and its oak backing.†

A nickel-steel armour plate was tried at Indian Head on February 11. The plate was 9 by 7 feet, and 14 inches in thickness. Four shots were fired with striking velocities of 1472, 1860, 1960, and 2000 feet per second. The first entered 5 inches and broke up, the second and third both penetrated about 6½ inches and partly cracked the plate, and the fourth shot entered about 10 inches, and cracked the plate in several directions, also breaking the backing.‡

Tests were made, on March 22, near Bethlehem, Pennsylvania, of a

* *Iron Age*, vol. l. p. 1025.

† *Ibid.*, vol. li. pp. 417-419.

‡ *Engineering and Mining Journal*, vol. lv. p. 155; *Industries*, vol. xiv. pp. 278-279.

nickel-steel plate. The plate was 16 by 8½ feet, and 12 inches in thickness. Three projectiles weighing 250 lbs., with initial velocities of 1678, 2004, and 1835 foot-seconds, were fired. The plate was not cracked.*

A photograph of the plate, and an account of the trial of the Harvey plate on the *Nettle*, November 1, is given.† An account of the Ochta trials made in November last is also published, with some illustrations of the plates.

At Ochta, on December 13, a Vickers solid steel plate, 10 inches thick, treated by the Harvey process, was tested. Four 90-lb. shots were fired at it with an average striking velocity of 2173 feet per second. Each shell penetrated 4 to 5 inches, and broke up without cracking the plate. Two projectiles, each of 406 lbs., were then fired with striking velocities of 1655 and 1889 feet per second, with the result of entirely breaking up the plate. ‡

An illustrated account of the various recent armour trials is given by Captain Orde Brown in the *Naval Annual*§ for 1893.

Wire-Gun Manufacture.—Mr. N. B. Whittman‖ describes the 5-inch Brown wire-gun, which was being manufactured at Birdsboro. The lining consists of crucible chrome steel, 18½ feet long, 3 inches thick at the breech, tapering to 0·8 inch at the muzzle. The tensile strength is 165,000 lbs., elastic limit 105,000 lbs., and elongation 14 per cent. on 2 inches. Square steel wire of 0·005 square inch sectional area is wound on at a tension of 650 lbs. on each strand. The wire has a tensile strength of 250,000 lbs. per square inch, elastic limit 200,000 lbs., and torsional strength 30 full turns in 8 inches before breaking. Thirty-three layers of wire, or 2·31 inches, are used at the breech, and ten layers, or 0·71 inch, at the muzzle.

* *Engineering and Mining Journal*, vol. lv. p. 274; *Engineer*, vol. lxxv. p. 286.
† *The Engineer*, vol. lxxiv. pp. 427, 483, 539; vol. lxxv. p. 256.
‡ *Iron*, vol. xl. p. 537.
§ Pp. 301–320.
‖ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

CHEMICAL PROPERTIES.

The Classification of Steel.—A. Semlitsch * observes that the classification of steel and ingot iron, for which it is customary in Austria-Hungary to adopt the Tunner scale, is subject elsewhere to very considerable variation, as will be seen from the following table :—

No.	Hardness.	Scale.			
		Tunner, Carbon per Cent.	Eggertz, Carbon per Cent.	Zeltweg, Carbon per Cent.	Neuberg, Carbon per Cent.
2.	Medium	1·25	1·25	...	...
	Soft	1·17	1·08	...	...
3.	Hard	1·08	1·00	...	From 1·12 to 0·88
	Medium	1·00	0·92	...	
	Soft	0·92	0·83	...	
4.	Hard	0·83	0·75	0·837	From 0·88 to 0·62
	Medium	0·75	0·67	0·772	
	Soft	0·67	0·58	0·652	
5.	Hard	0·58	0·50	0·557	From 0·62 to 0·38
	Medium	0·50	0·42	0·503	
	Soft	0·42	0·33	0·451	
6.	Hard	0·33	0·25	0·374	From 0·38 to 0·15
	Medium	0·25	0·17	0·295	
	Soft	0·17	0·13	0·207	
7.	Hard	0·13	...	0·183	From 0·15 to 0·05
	Medium	0·05	...	0·145	
	Soft	...	...	0·127	

Segregation in Steel.—Mr. T. W. Hogg † gives a large number of analyses of metal from different portions of a mild steel cylindrical ingot weighing 11 tons 1 cwt., 10 feet long and 30 inches in diameter:—

* From the Hungarian, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 2.

† *Journal of the Society of Chemical Industry*, vol. xii. pp. 236–239.

Elements.	Face of Top.			Bottom.		
	Centre.	1 Inch from Centre.	Near Edge.	Centre.	1 Inch from Centre.	Near Edge.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron . . .	98·40	98·60	99·30	99·30	99·40	99·30
Manganese .	0·27	0·25	0·20	0·22	0·21	0·22
Carbon . .	0·75	0·58	0·20	0·24	0·24	0·24
Silicon . .	0·042	0·034	0·03	0·034	0·034	0·034
Sulphur . .	0·15	0·12	0·036	0·037	0·037	0·037
Phosphorus .	0·20	0·10	0·042	0·050	0·047	0·047
Copper . .	0·052	0·052	0·054	0·048	0·054	0·054
Total .	99·864	99·736	99·862	99·929*	100·022	99·932

Drillings as follows were also analysed for carbon; the hole, drilled from the centre upwards, encountered a contraction cavity at a depth of 11 inches:—

A.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
B.	0·75	0·75	0·79	0·86	0·80	0·79	0·75	0·70	0·75	0·71	0·73	...	...	...
C.	0·58	0·60	0·61	0·70	0·70	0·65	0·60	0·60	0·61	0·61	0·61	0·60	...	...
D.	0·75	0·66	0·70	0·60	0·61	0·58	0·50	0·50	0·40	0·40	0·40	0·39	0·39	0·32

A, distance in inches from centre; B, carbon per cent. from centre upwards; C, one inch from centre upwards; D, from centre downwards.

These results show that the central core of impure metal is elongated and not abrupt, as sometimes, though rarely, occurs. The core itself does not greatly lessen the strength of the metal, as may be seen by comparison with a cored-out shaft. The author thinks that failure may sometimes be ascribed to a partial re-absorption of impurities, which may take place during long-continued soaking heats.

As an example of abrupt segregation, the example of a steel roll given by H. Reuss † is quoted, and also analyses of a stalactitic formation in a contraction cavity of a large steel ingot:—

	Fe.	Mn.	C.	Si.	S.	P.	Cu.	Total.
Stalactite .	98·70	0·49	0·36	0·074	0·033	0·048	0·064	99·769
Ingot . . .	98·70	0·43	0·28	0·060	0·030	0·039	0·064	99·603

Globules are sometimes found on the outside of large steel castings. In one case the brittle ones contained 5·24 per cent. of combined carbon

* 99·939 in original.

† *Journal of the Iron and Steel Institute*, 1891, No. II., p. 299.

and 0·30 per cent. of manganese, and more malleable though still brittle specimens gave :—

	Fe.	Combined C.	Graphitic C.	Si.	Mn.	S.	P.
Globules . . .	94·70	1·00	2·54	0·68	0·20	0·17	0·14
Original steel . .	...	0·35	traces	0·30	0·80	0·04	0·05

On breaking pigs, a fine-grained patch is often found near the centre, an analysis of which compared with the exterior is given below :—

	Mn.	Combined C.	Graphitic C.	Si.	S.	P.	Cu.
Centre . . .	0·92	2·93	0·39	2·42	0·036	0·033	0·10
Exterior . .	0·91	3·60	0·44	2·42	0·036	0·033	0·10

A similar appearance is often seen in the gits of steel castings, but this is due to the recarburisation of the exterior by the charcoal blacking thrown on the top of the feeder.

Mr. W. E. Koch * gives an analysis of open-hearth steel rails showing segregation. The analytical results were as follows :—

	At Surface.	1 Inch from Surface.
Carbon	0·13	0·15
Phosphorus	0·28	0·46
Sulphur	0·06	0·06
Manganese	0·60	0·62

In steel plates similar conditions have been observed. The following shows the composition of one that cracked after having been built into a boiler in 1880 : —

Carbon	0·07 to 0·13
Sulphur	0·08 to 0·15
Phosphorus	0·04 to 0·06
Manganese	0·60 to 0·68

This plate was rolled from a slab hammered out of an ingot about 18 inches thick.

Other experiments with plates rolled from large ingots showed a distinct segregation of phosphorus, sulphur, and carbon at the centre of the plate.

The Solubility of Carbon in Iron.—H. Moissan † states that if iron is saturated with carbon at temperatures varying between 1100° and 3000° C., different results are obtained at the different temperatures.

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. ix. No. 2, pp. 23-26.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 218.

Thus, between 1100° and 1200°, a mixture of amorphous carbon and graphite results on the solution of the metal, while from a temperature of 3000° only graphite, and that in fine crystals, is obtained. If the iron when cooling is exposed to high pressure, some of the graphite is converted into the diamond form. This pressure the author obtains by melting wrought iron in an electric furnace, in a quantity of about 150 to 200 grammes for a few minutes, then plunging into the bath an iron capsule, plugged, and filled with strongly compressed carbon obtained by the decomposition of sugar. As soon as this cylinder has been plunged into the bath, the crucible containing the iron is removed from the furnace and plunged into water. The outside of the iron becomes solidified, and as soon as this cooled surface is at a dull red heat the mass is taken out of the water and allowed to cool in the air. On solution in boiling hydrochloric acid, several varieties of carbon residues remain, and amongst these are fragments having a specific gravity varying between 3·0 and 3·5, and of a hardness sufficient to scratch a ruby. On heating in oxygen, it is found that these fragments are really diamonds, most of which are of the black or carbonado form, while occasionally true transparent diamonds result.

The Occlusion of Hydrogen by Iron.—G. Neumann and F. Streintz * show that iron in a fine state of division absorbs 19·17 times its volume of hydrogen; copper, 4½ times; nickel, 17·57 volumes; lead, 0·15 volume; palladium black, 502·35 times its volume; platinum sponge, 49·3 volumes; gold, 46·3 volumes; silver, none; aluminium, 2·72 volumes; and cobalt, a considerable quantity.

Of oxygen, silver absorbs 4·09 volumes; platinum, 77·14 volumes; gold, 48·49 volumes; while in the case of palladium a sub-oxide is formed, containing 6·99 per cent. of oxygen.

Iron-Carbonyl in Illuminating Gas.—Guntz † believes that a deposit of ferric oxide observed by him on the glasses and reflectors of gas-lamps is due to the presence of iron-carbonyl in the gas, this compound having probably been formed by the interaction of the carbonic oxide contained in the gas, and the iron used as a desulphurising agent.

The author does not refer to the similar observation of Sir H. Roscoe and Dr. Thorne.‡

* *Zeitschrift für Analytische Chemie*, vol. xxxii. p. 72.
† *Bulletin de la Société Chimique*, vol. vii. pp. 281–282.
‡ *Proceedings of the Chemical Society*, 1891, p. 126.

The Action Exerted by Iron on Carbonic Oxide.—The question of the action of finely divided iron and manganese on carbonic oxide has been studied by Guntz, and his observations are discussed by C. G. Särnström.* At a temperature of 500°, it has been shown by Stammer that a current of carbonic oxide will reduce ferric oxide with the deposition of amorphous carbon. Schützemberger, on the other hand, has pointed out that carbonic oxide free from carbonic anhydride, if passed over iron, is decomposed with the formation of C and CO_2. By distilling *in vacuo* at a temperature of 250° or 280° their amalgams, best obtained electrolytically, both iron and manganese are left in a very finely divided condition. If a current of carbonic oxide be passed over these metals heated in a glass tube, the carbonic oxide is found, as has been shown, to enter into combination with them, being absorbed at first without evolution of gas, the reaction probably being $Mn + CO = MnO + C$, or $Fe + CO = FeO + C$. Other reactions also take place, as Moissan has shown, such as $2Mn + CO_2 = 2MnO + C$, all explaining the deposition of carbon. Särnström refers especially to Sir Lowthian Bell's experiments, the results of which were published in the first volume of the *Journal of the Iron and Steel Institute*, which are practically identical with those referred to by the author.

Oxygen in Malleable Iron.—Mr. P. Gladky † discusses the part that is played by the oxygen which is present in malleable iron. The author assumes that of the various impurities present in this metal, any metallic ones will exist as alloys with iron that are dissolved in the mass of metal. These, he considers, exert an entirely different kind of influence on the iron to that which is exerted by the metalloids. These latter enter into chemical combination with the iron, and place themselves between its molecules. If, for instance, 0·08 per cent. of sulphur is present, this represents 0·22 per cent. of iron sulphide, and one is therefore justified rather in referring to the influence exerted by the iron sulphide than to that of the sulphur as such. This appears, too, to be the more justifiable when it is remembered that a percentage of 0·22 of slag in the metal would exert a similar influence. Hard metals, the author thinks, harden iron, because they themselves are hard, while a metal such as copper does not deleteriously affect the properties of malleable iron, because it in itself is a malleable and ductile metal. On the

* *Teknisk Tidskrift*, vol. xxiii. p. 61.

† From the Russian *Mining Journal*, vol. ii., 1892, p. 72; through *Stahl und Eisen* vol. xiii. pp. 245 and 293.

other hand, the influence of their combinations cannot be so accurately foretold, but elements possessing similar properties probably act in an identical manner, the author coupling in this respect arsenic with phosphorus, and oxygen with sulphur. According to Ledebur, there is never more than 0·25 per cent. of oxygen, equivalent to 1·14 per cent. of FeO, present in ingot iron, and this is quite sufficient to render it red-short. This fault is less observable in ingot iron than it is in weld iron. Red-shortness, when it does occur, is usually attributed to sulphur, copper, or some other cause, although more than 0·5 per cent. of oxygen has been found in weld iron, and this, too, being unequally distributed, would be yet the more dangerous in its effects. At the Taghil Works in the Ural, blooms are made by the Tunner method. To obtain a homogeneous material these blooms are returned to the furnace four or five times. The consequence is that they get contaminated with slag, and the metal becomes red-short. Samples of such blooms, which were distinctly red-short, showed from 0·06 per cent. to 0·20 per cent. of carbon, 0·00 to 0·08 of silicon, 0·00 to 0·02 of sulphur, 0·00 to 0·22 of copper, 0·00 to 0·06 of phosphorus, and 0·14 to 0·33 per cent. of oxygen, equivalent to 0·63 to 1·51 per cent. of ferrous oxide. These were all too red-short for use, but other blooms which contained less than the above quantities of oxygen were free from this fault, although one contains 0·18 per cent. of copper.

Good puddled iron containing from 0·20 to 0·25 per cent. of carbon contains but very little oxygen, the following being analyses of such metal from the Saldinsky and Laïsk Ironworks :—

	C.	Si.	Mn.	S.	Cu.	P.	O.	=FeO.
I. . . .	0·25	0·084	0·14	0·004	0·15	0·012	0·066	0·29
II. . . .	0·23	...	...	...	...	...	0·052	0·23
III. . . .	trace	0·090	0·07	0·000	0·16	0·039	0·101	0·45

No. III. metal was of exceptionally good quality. The influence of oxygen appears often to be overlooked, the author instancing three analyses of puddled rails made at the Laïsk Works, which while containing but a trace of carbon and manganese, with 0·02 to 0·12 of silicon, 0·008 to 0·03 of sulphur, 0·00 to 0·02 of phosphorus, and 0·15 to 0·17 of copper, could not be rolled satisfactorily. The very low percentage of carbon led the author to conclude that oxygen was present. Still, as

the author observes, it is quite possible to produce an excellent material even though the percentage of carbon is low, provided that the metal has been properly treated, as is to be seen from the third analysis in the table given above. With a view to ascertain the truth of his opinion as to the bad results being due to the presence of oxygen, the author analysed these samples of metal again, and found, as he had foreseen, that they contained a large percentage of oxygen, amounting to 0·294, 0·448, and 0·423 per cent. in the respective rails.

As showing the percentages of oxygen which occur in ingot metal, the author gives the following analyses :—

	C.	Si.	Mn.	S.	Cu.	P.	O.	= FeO.
I. . . .	0·14	0·016	0·07	0·004	0·12	0·038	0·033 0·021	0·23
II. . . .	0·06	trace	0·21	...	...	...	0·045	0·20
III. . . .	0·14	0·020	0·04	0·008	0·14	0·08	0·064 0·044	0·28
IV. . . .	0·20	0·010	0·23	0·004	0·15	0·06	0·045	0·20
V. . . .	0·24	0·046	0·32	trace	0·10	0·07	0·074 0·040	0·33
VI. . . .	0·39	0·046	0·20	trace	0·14	0·09	0·037 0·032	0·16
VII. . . .	0·14	0·280	0·18	0·103	0·10	0·06	0·030	0·13

In the oxygen determinations where two results are given, the upper ones in the table represent those obtained with filings, and the lower ones with turnings. Nos. I. and II. were acid open-hearth metal; III. and IV., metal from a chrome-ore lined open-hearth; V., a Bessemer ingot; VI., a Bessemer rail; and VII., a Bessemer sheet.

The author considers that in determining the quality of iron the percentage of oxygen should be added to that of the sulphur to obtain the desired information. It has been shown, he adds, that sulphur is less deleterious in the presence of but little carbon than it is when the percentage of that element is high, and it is therefore difficult to decide what percentages of oxygen and sulphur taken together are sufficient to seriously affect the iron. The following are some analyses of harder steels :—

	C.	Si.	Mn.	S.	Cu.	P.	Cr.	O.	= FeO.
I. . . .	0·65	0·17	0·18	0·01	0·13	0·058	...	0·082	0·37
II. . . .	0·75	0·39	0·28	...	...	...	0·18	0·041	0·18
III. . . .	0·72	...	...	...	...	...	...	0·062	0·28

Borings were used in the determination of the oxygen in the first metal, which was a puddled bar from the Saldinsky Works, whilst filings were used in the other two analyses, which were in both cases of open-hearth metal. It is probable, the author thinks, that the percentages of oxygen found in these three high-carbon steels were not really present in the original metal, but that the oxygen was due to inaccuracy in obtaining the borings or filings. If that assumption, however, is correct, it would appear to throw considerable doubt on the other oxygen results which have been referred to. Ledebur has stated that a percentage of oxygen amounting to 0·07 is without any deleterious action on iron, and his results, too, the author considers, are open to the same objection. The author further refers to the difficulties he has experienced in accurately obtaining samples.

In a subsequent communication, Professor A. Ledebur * observes that he has shown that 0·25 per cent. of oxygen in a sample that he examined had rendered the metal extremely red-short, though it could be worked easily at a white heat. The author doubts Gladky's statement that sulphur is not so deleterious in its action on iron when the percentage of carbon is low as it is when the percentage of that element is high, and draws attention to the inaccuracies in the statements made in the paper as to observations of his own. Referring to his early experiments on this subject, Ledebur observes that he was originally of the opinion that when manganese or silicon, or any other substance which could exert a reducing action on the ferrous oxide, was added to the metal, the oxygen would be completely eliminated from the metal. But this is not the case, as the resulting oxides of manganese, or silicon, &c., are retained by the metal much as the ferrous oxide was, and although the action of the oxygen has been changed, its influence has not been wholly eliminated. The author thinks that these secondary oxides are very possibly distributed in suspension through the metal, and that they are not necessarily dissolved. It is a difficult matter to determine the percentage of oxygen in iron. The author inclines to think Pourcel's method the best, the iron being heated in a current of chlorine, and the reduced soluble chlorides afterwards washed out, but owing to the changes which occur when iron is so treated, it would be impossible in this way to decide in what oxide the oxygen existed in the metal originally treated. At present, however, there is no method which admits of this being ascertained.

* *Stahl und Eisen*, vol. xiii. pp. 293–296.

A Crystalline Iron-Tungsten Alloy.—T. Poleck and B. Grützner* found that a lump of iron-tungsten alloy, obtained by an electrolytic method from wolfram, from Bohemia, consisted of a crystalline matrix of the composition $Fe_2W_3C_3$, containing small crystals of the composition FeW_2. Both the crystals, which are prisms of the hexagonal system, and the matrix are silver-grey in colour, very heavy, and as hard as corundum. The specific gravity of the matrix is 12·92 to 13·04.

The Alloys of Iron and Tin.—From a study of the formation of the alloys of tin and iron, Mr. W. P. Headden † concludes that there is a series of stannides of iron, of which he obtained the following members:—$FeSn_2$, Fe_2Sn_3, Fe_2Sn_4, Fe_4Sn_5, Fe_5Sn_6, FeSn, Fe_3Sn, Fe_4Sn, and Fe_9Sn. Some of these have been described before, but the published descriptions assign to them properties some of which differ widely from those observed by the author. All writers on these alloys agree in giving aqua regia as the solvent for them. The author, however, has invariably used hydrochloric acid, and has found but a small amount of any one of them insoluble in this agent, and the portion insoluble in it was almost as insoluble in aqua regia. The description of the crystal forms is also quite at variance. This may be due to a difference of interpretation of the forms, or it may indicate that the alloys vary greatly, both in form and in properties, according to the conditions under which they are produced. The author's observations tend to establish the latter theory.

An Iron-Nickel Alloy.—Mr. D. H. Brown,‡ on breaking a pot of copper-nickel matte, found a cavity lined with brilliant tin-white crystals. They were highly magnetic, exceedingly tough and flexible, and only sparingly soluble in hydrochloric or sulphuric acids. In hot dilute nitric acid they were, however, readily soluble, leaving no siliceous or carbonaceous residue. On analysis, the crystals were found to have the following composition, which, if the copper be excluded, as it appeared to be partly mechanically included, would correspond to the formula Fe_8Ni_9:—

Copper.	Iron.	Nickel.
4·89	43·3	52·1
3·64	44·0	52·0

* *Berichte der Deutschen Chemischen Gesellschaft*, vol. xxvi. pp. 35-38.

† *American Journal of Science*, vol. xliv. pp. 464-468.

‡ *Journal of Analytical and Applied Chemistry*, vol. vi. pp. 150-152.

Magnesium-Zinc Iron Alloys.—Alloys of magnesium-zinc and iron, according to Mr. H. N. Warren,* are used in pyrotechny. By one method they are produced by the electrolysis of sodium and magnesium chloride in the presence of zinc, ferrous chloride being subsequently added and electrolysed. By another method an alloy of sodium and zinc is caused to act first on a mixture of sodium and magnesium chlorides, and then on ferrous chloride. Alloys containing 12 per cent. of iron are thus obtained.

Iron-Aluminium Alloys.—Mr. T. W. Hogg † has investigated the influence of aluminium upon the carbon in ferro-carbon alloys, and the specific gravity of pure ferro-aluminium. By melting separately, and mixing 42 lbs. of Swedish pig iron, containing 3·90 per cent. of carbon, of which 0·85 was combined with 5 lbs. of aluminium, an alloy was produced containing—

Aluminium.	Silicon.	Combined Carbon.	Graphitic Carbon.
11·30	0·51	3·14	traces.

In another experiment the combined carbon was 3·85, with no graphitic carbon. To find the limit of saturation with carbon, an alloy of iron and aluminium was melted with a large excess of charcoal, and the result obtained was :—

Aluminium.	Combined Carbon.	Graphitic Carbon.	Total Carbon.
17·18	2·81	0·21	3·02

Ferro-manganese would contain twice as much carbon, and ferro-silicon half this amount.

The following alloys contain but little carbon :—

Fe.	Mn.	C.	Si.	S.	P.	Al.	Specific Gravity.
89·90	traces	0·11	0·065	0·010	0·037	9·62	6·99
79·86	traces	0·07	0·040	traces	0·030	20·00	6·31

They are crystalline and lustrous, and the first one can scarcely be distinguished from phosphor-tin. The specific gravity of these two alloys was determined as 6·99 and 6·31 respectively. The calculated values are 6·54 to 6·65, and 5·59 to 5·69, according to the values taken for the components, so that the real values are considerably higher than the calculated values.

The Cause of the Formation of Rust.—S. Weinwurm ‡ describes

* *Iron*, vol. xli. p. 165.

† *Journal of the Society of Chemical Industry*, vol. xii. pp. 239-240.

‡ *Chemiker Zeitung*, vol. xvii. p. 101.

a case in which some steel plates delivered to an Austrian railway company, to be laid below the rails, were found to rust with extreme rapidity. An analysis was made of the rust, and it was found to contain :—

	Per Cent.
Water	2·72
Ferrous oxide	9·52
Ferric oxide	81·69
Combined carbon	0·68
Graphite	0·10
Sulphur	0·51
Sulphuric anhydride	0·24
Carbonic anhydride	0·70
Manganese oxide	0·57
Lime	1·23
Phosphorus	0·05
Silica	1·65
Zinc	traces
Total	99·66

The metal itself contained—

Fe.	Graphite.	Combined Carbon.	Mn.	Si.	S.	P.	Ca+Mg.
98·43	0·08	0·33	0·20	0·14	1·08	0·04	traces

From these analyses it follows that the formation of the rust was due to the very large percentage of sulphur that was present in the metal.

Iron Rust with Magnetic Properties.—As a specimen of rust from some old tram-rails was found to possess magnetic properties, Professor A. Liversidge * investigated the character of a large number of samples, and found that a very large percentage of the mass in each case was attracted by the magnet. Precautions were taken to prevent metallic iron being present. The conclusions drawn from these experiments, and from some others on the occurrence of magnetite in certain ores and rocks, are, that native ferric oxide and its hydrates, such as hæmatite, limonite, goethite, &c., are themselves non-magnetic, but may contain some magnetite. Sesquioxide of iron obtained by precipitation from the acid carbonate is magnetic, or may be rendered so by long boiling, or by heating at various temperatures up to redness, and it is free from monoxide. Magnetic sesquioxide free from the monoxide can be obtained by heating the magnetic oxide. Ordinary rust produced by oxidation of iron is usually magnetic, and

* *Transactions of the Australasian Association for the Advancement of Science*, 1892; *Iron*, vol. xl. pp. 492 and 558.

often polar. It usually contains a mixture of ferrous and ferric oxides, and their hydrates which possess magnetic properties, although in other cases it may be free from monoxide and yet be magnetic.

The Corrosion of Iron.—B. Kosmann * discusses the question of the corrosion by water of both ingot and weld iron. The author considers the different degrees of resistance shown by these two metals to be due not so much to the different modes of preparation of the two materials, as to the immediate result of differences in both the chemical and physical constitution of ingot and weld iron. The cause of the difference in the resistance to corrosion is not, that is, to be sought for in the presence here or there of a blow-hole in the ingot iron, or of a piece of slag in the weld iron, but in the fact that the two metals have different chemical compositions, and that these in turn, causing a difference in the molecular structure of the metal, form the basis on which depends the varying behaviour of the metals both to chemical change and to the influence of varying temperature. The author ridicules the use of the term "alloy," especially as employed in the case of iron containing carbon and other impurities, and he refers in this connection to the work of Matthiessen in 1867, and to the recent Cantor Lectures on "Alloys" of Roberts-Austen. No one thinks of calling the sulphur and phosphorus compounds with metals as alloys, and yet carbon, possessing a smaller molecular weight than either sulphur or phosphorus, is consequently much more capable of forming chemical combinations with other elements than either of these metalloids. Similar objections may be made to the use of the word "alloy" for the combinations of iron with nickel, manganese, aluminium, chromium, and tungsten. The formation of the needle-shaped crystals of ferro-chromium must be considered as affording evidence of the existence of a chemical compound, the homogeneous molecular arrangement of which is made externally evident by the crystalline form of the alloy. Years ago Schneider proved the existence of a well-crystallised compound containing 69·38 per cent. of tungsten and 28·35 per cent. of iron in ferro-tungsten, and crystals of the compounds FeW_2 and $Fe_2W_3C_3$ have also been isolated. So, too, with the other metals. As to the influence of carbon, the author quotes the results obtained by Helge Bäckström and Gunnar Pajkull on the volume and percentage of carbon of the gases evolved when iron and steel are dissolved in acids. The author observes that these results prove, as indeed Berzelius stated, that not

* *Stahl und Eisen*, vol. xiii. pp. 149-152.

the whole of the combined carbon passes into the gas evolved on the solution of the metal. Further, that the portion of the carbon which passes away as a hydrocarbon is not proportional to the percentage of combined carbon contained in the metal; that none of the numerous varieties of iron and steel examined gave off either the whole or any definite proportion of the carbon they contained as hydrocarbon, although the total percentage of carbon in the samples varied within the very wide limits of less than 0·2 to as much as 6·37. Neither is the volume of the gas produced proportionate to the percentage of combined carbon contained in the metal dissolved, and the only positive results that these experiments gave were, that hydrochloric acid, when used as a solvent, gives larger volumes of gas than does sulphuric acid, the gas being also richer in carbon; that, as a rule, a larger volume of gas is accompanied by a diminution in the percentage of carbon, though not a proportionate one; and, finally, that that portion of the carbon which does not escape as gas, but remains in the solution, retains in combination large quantities of hydrogen, thus diminishing the observed volume of the gas resulting from the solution. This must all depend on the way the carbon exists in the iron, and the author refers to the experiments made by different investigators in connection with this subject, and he considers that it is due to the quantity and the composition of the combined carbon—of the iron carbide, that is—which occurs in the metal, that the variations observed in the quantity and composition of the gas is due.

The quantity of hydrocarbons that is evolved is not always in strict relation to the percentage of "combined" carbon contained in the iron, as, in consequence of the heat given off when the metal is attacked with acid, the hydrocarbons evolved are usually partly decomposed with the deposition of solid carbon. There is consequently no doubt but that the solution of an iron which contains carbon is a matter involving much complicity of reaction, and that much caution is necessary when drawing conclusions as to the nature of the iron treated from the composition of the products obtained in its solution in acid. Nitric acid is a solvent whose action on iron, while energetic, yet can be followed better than that of most other solvents. Take the case of a piece of hardened steel dipped in the acid. It becomes covered with a coating of carbon. The question may be asked, whether the reaction in this case is not similar to the decomposition of a sulphide by nitric acid? It leads to the conclusion that the carbon does not exist in the iron simply as a dissolved material, but that it is in some state of combination which the nitric acid can decompose, a true chemical compound—a carbide,

although the actual composition of this carbide is still a matter of doubt. The oxidation of the hydrogen which is evolved at the same time as the carbon does not simply lead to the formation of water, but it also leads to the hydration of the liberated carbon, the OH of the OH – H group combining with carbon, the hydrogen finding for itself a new molecule of oxygen. It follows that the solution of iron is not effected, as has been thought, without the evolution of nascent hydrogen, but that this hydrogen combines with the deposited carbon, and it is to this that is due the formation of the hydrocarbides, which are obtained as a residue when iron containing carbon is dissolved by such salts as chlorides or sulphates, or by the electric current. The author is of opinion that the changes observed by Osmond are in reality due to a rearrangement of the atoms within the molecules of the iron carbide present. He considers that the molecules undergo a change analogous to that of other organic carbides, larger and more complex molecules being produced as the temperature of the metal rises, and simpler and smaller molecules as the temperature falls. Even small alterations of temperature should suffice to bring about such molecular changes.

CHEMICAL ANALYSIS.

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I.—*ANALYSIS OF IRON AND STEEL.*

The Analysis of Iron and Steel.—The causes of discrepancy in chemical analysis are discussed by Dr. C. B. Dudley,* with special reference to the determination of carbon, sulphur, and other constituents in iron and steel. There are four main causes of error to which discrepancies may be attributed. These are—(1) the sample may not be the same; (2) the degree of purity of the chemicals varies; (3) the personal error in manipulation; (4) the use of different methods. As regards the first cause, the author has not had much trouble, though in one case he cites the fact that samples taken from the exterior and from the core of some steel springs gave different percentages of carbon. The second cause is familiar to every one. There are two ways of counteracting its effects: either the chemicals should be tested, or a blind test made. The first is not always feasible, and even the second is far from satisfactory, as the reactions may vary owing to the absence of the elements in the sample. The third cause, that of personal error, introduces discrepancies through difference of manipulation. This often arises from the indefinite nature of the instructions, or from the inaccuracy in the amount of reagents used, or of the time employed. In one case, an interval of two days in the determination of silicon in steel by Brown's method caused the result to be just half of what it should have been. The fourth cause is one that can be easily eliminated, and the author proposes that in every specification the test shall be included. This the author is endeavour-

* Paper read before the Engineers' Society of Western Pennsylvania, Chemical Section, September 27, 1892.

ing to introduce in the specifications of the Pennsylvania Railroad Company.

Messrs. J. Parry and J. J. Morgan,* in a series of articles, deal with the analysis of iron and steel, and summarise the methods now used for the determination of silicon, phosphorus, total combined, and graphitic carbon, by colorimetric and other methods, also copper, tungsten, oxygen, titanium, manganese, arsenic, chromium.

The Determination of Carbon.—C. Reinhardt† has modified the apparatus as originally devised by him‡ for the determination of the total carbon in iron in such a manner as to avoid the use of a current of electricity in the combustion of the carbon. Instead, he now uses either red-hot platinised asbestos, or, preferably, platinised pumice-stone, similarly heated. The gaseous products resulting from the solution of the metal are passed over the heated oxidising material, and the combustion is stated to be complete. The method of arrangement employed by the author is described, as also is the method of preparation of the platinised pumice, in which use is made of the readiness with which platinum ammonium chloride decomposes.

The Determination of Manganese.—M. Bastin has published§ the following method of determining manganese in spiegeleisen and ferro-manganese:—Dissolve from 0·25 to 1 gramme according to the manganese content in 50 cubic centimetres of nitric acid of 1·2 specific gravity; add 8 to 10 grammes of chlorate of potassium; boil 15 minutes, dilute, filtrate, and titrate with oxalic acid.

R. B. Riggs‖ discusses the separation of iron, manganese, and calcium by means of the ammonium acetate method. He points out that in the precipitation of the iron too large an excess of ammonium acetate is to be avoided, and the precipitate that is formed should not be heated too long nor too strongly while in the solution. During the previous neutralisation there is a tendency for some of the manganese to be precipitated. The use of ammonium salts permits of the quantity so precipitated being reduced to a minimum, though even then some of the manganese comes down. The precipitate should be redissolved and again precipitated.

* *Industries*, vol. xiv. pp. 90, 115, 187, 330, 427, 475, 499, &c.
† *Journal of the Iron and Steel Institute*, 1892, No. II., p. 511.
‡ *Stahl und Eisen*, vol. xii. p. 1040.
§ *Berg- und Hüttenmännische Zeitung*, vol. lii. p. 48.
‖ *Journal of Analytical and Applied Chemistry*, 1892, p. 94; *Stahl und Eisen*, vol. xiii. p. 119.

The precipitation of the manganese by bromine in ammoniacal solution is greatly facilitated by the presence of acetate, and the precipitation is best effected by the addition of bromine water to a hot ammoniacal solution. If more than about five grammes of manganese is present, the precipitate must be redissolved and reprecipitated.

The Determination of Phosphorus.—Some notes on Emmerton's method for the determination of phosphorus are given by Mr. H. C. Babbitt.* Arsenic is precipitated with the phosphomolybdate to an amount exceeding the limit of error in the phosphorus determination, if precipitation is done at a temperature exceeding 25° C. Although differing degrees of dilution affect the amount of arsenic precipitated, yet, at this temperature, the error is negligable. The author has also investigated the composition of the precipitated ammonium phosphomolybdate by several methods. Dried at 180° C. it contains :—

$(NH_4)_2O_3$.	P_2O_5.	MoO_3.	H_2O.
4·091	3·724	90·315	0·990

The average of the several methods gave 1·626 per cent. of phosphorus. The methods used for the analysis are given. For reducing the molybdic oxide before titration with potassium permanganate, the solution was passed through a column of powdered zinc, and the results compared with Emmerton's original method of treating with zinc. The speed of reduction has considerable effect when less than two minutes is given. It is found that all the phosphorus is precipitated at 25° C. with five minutes' shaking, and that the ratio of phosphorus to molybdic acid is constant in the precipitate, even when ferric nitrate is present.

A. Carnot† describes a method of determining phosphorus in iron and steel, in which silicon is separated by sulphuric acid, chromic acid employed to destroy carbon compounds, and the phosphorus precipitated as ammonium phosphomolybdate. To the nitric acid solution of the sample, two cubic centimetres of sulphuric acid per gramme of iron are added, and the solution is evaporated to dryness and heated at 120° to 125° C. for two hours. The mass is dissolved, filtered, and one gramme of chromic acid is added. The solution is boiled, and the phosphorus is precipitated by the molybdic solution. After standing, the precipitate is filtered off, washed and dissolved in ammonia. The phosphomolybdate is reprecipitated by the addition of nitric acid at a temperature not above

* *Transactions of the American Institute of Mining Engineers*, Montreal Meeting (advance proof).

† *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. pp. 106-108.

40°. After standing two hours at this temperature, the precipitate is filtered off, dried at 100° C., and weighed. It contains 1·628 per cent. of phosphorus.

Mr. F. L. Crobaugh * points out that in the estimation of phosphorus by the reduction of the molybdate precipitate with zinc and sulphuric acid, and subsequent titration with potassium permanganate, there is a liability to error on account of the oxidisable matter contained in a sulphuric acid solution of zinc. Some experiments were made to determine this error, and the results are given.

Mr. J. O. Handy † describes a modification of Manby's method, in which the phosphorus, after being deposited as pure ammonium phosphomolybdate, is dissolved in caustic soda, and the excess of the soda titrated back with nitric acid and phenolphtalein. The acid reaction is very distinct. As the reducing agent the author uses pure cane-sugar.

In effecting the determination, 2 grammes of the steel are dissolved in 75 cubic centimetres of nitric acid of 1·13 specific gravity, and then 15 cubic centimetres of a solution of 5 grammes of permanganate in 1 litre of water is added to the boiling iron solution, the boiling being continued until the pink tinge has disappeared. Both the carbon and the phosphorus are completely oxidised, a brown precipitate of manganese oxide remaining. Only in the case of high-carbon metal is more permanganate required. An addition of 0·033 gramme of sugar is then made, and the solution boiled until it has become clear. The flame being removed, 13 cubic centimetres of ammonia of 0·90 specific gravity is added carefully after two or three minutes, the solution being shaken until the ferric hydrate has re-dissolved. When the solution has reached the temperature of 85° C., 50 cubic centimetres of molybdate solution is added, the bottle is stoppered, shaken in a shaking apparatus for five minutes, and then immediately filtered. After frequent washing, first with a 1 per cent. solution of nitric acid, and then with a similar solution of potassium nitrate, the filter and its contents are charged into a flask, from 10 to 20 cubic centimetres of a standard solution of caustic soda is added, the whole shaken to dissolve the precipitate, and then diluted with water to 50 cubic centimetres. After adding three drops of the solution of phenolphtalein the titration is effected with a standard solution of nitric acid, the end reaction being shown by the disappearance of the pink tinge from the solution. An assay can be completed, the author states, in thirty minutes.

* *Journal of Analytical and Applied Chemistry*, vol. vi. pp. 483–485.
† *Chemical News*, vol. lxvi. p. 324.

The ammonium molybdate solution is obtained by dissolving 1 lb. of molybdic acid in 1200 cubic centimetres of water, stirring in 700 cubic centimetres of ammonia of 0·90 specific gravity, and mixing with 300 cubic centimetres of nitric acid of 1·42 specific gravity. Every 550 cubic centimetres of this solution is added to 500 cubic centimetres of 1·42 nitric acid, and 1200 cubic centimetres of water. The caustic soda solution is obtained by dissolving 15·4 grammes of caustic soda in 100 cubic centimetres of water, and adding a saturated solution of barium hydrate until no more precipitate is formed, filtering rapidly, and diluting to 2 litres. The nitric acid solution is made of the same standard as the soda solution. One gramme of pure ammonium phosphomolybdate is used in standardising. If the standard solutions are either too strong or too weak, they are diluted or strengthened to whatever extent is required to make 1 cubic centimetre equivalent to 0·0002 gramme of phosphorus.

N. von Lorenz * discusses the sources of error in the determination of phosphoric acid by magnesia mixture. These mainly consist in the precipitation of magnesia with the phosphorus precipitate. This can be avoided by the addition of 2 per cent. of ammonium citrate before the precipitation with magnesia mixture, no magnesia being then precipitated. The magnesia mixture should be added drop by drop, except when much citrate is present.

Messrs. W. Macfarlane and A. Wilson † describe the methods used for the determination of phosphorus by the Glengarnock Iron and Steel Company. By the standard method, 2 grammes of the metal are dissolved in 15 cubic centimetres each of nitric and hydrochloric acid. The solution is evaporated to dryness, allowed to stand on the hot plate for ten minutes, cooled, and the residue taken up with hydrochloric acid and then boiling water. After filtration, the solution is neutralised with ammonia, and the iron reduced by ammonium bisulphite. Excess of sulphurous anhydride is boiled off, ferric chloride sufficient to combine with the phosphorus is added, and ferric phosphate is precipitated by ammonium carbonate. The precipitate is dissolved off the filter by hot dilute hydrochloric acid, neutralised with ammonia and nitric acid, and 200 cubic centimetres of molybdate solution is added to the solution at 85° C. The precipitate is filtered off, dissolved in ammonia, neutralised with hydrochloric acid, and the phosphorus precipitated by magnesia mixture and ammonia. The precipitate is dried, ignited, and weighed.

For the rapid method, a fractional portion of the solution is taken,

* *Zeitschrift für Analytische Chemie*, vol. xxxii. p. 64.

† Paper read before the West of Scotland Iron and Steel Institute, January 1893.

ammonia added, and neutralised with hydrochloric acid. Ammonium nitrate solution and then molybdate is added. The solution is heated to 85° C., well shaken, and the precipitate is filtered off, washed, and transferred to a tared basin, in which it is dried and weighed. This is used for pig iron, but a similar method is used for slag and for steel, full particulars being given of all the processes. The authors state that, for good results with the molybdate method, it is necessary to have concentrated solutions, to use definite quantities of reagents, and not to have too great a weight of precipitate. Some comparative results are given to show the accuracy, and some of the results are plotted as curves. Particulars are also given of the methods of preparing the reagents.

L. Schneider * continues a series of articles on the analysis of steel. The earlier application of the molybdate method was not a success, and analysis results based on this method published prior to 1878 are usually much too low—by one-third or one-fourth of the total quantity originally present. Lamm, who discovered this error, thought it was due to the incomplete precipitation of the phosphorus in the presence of organic salts. To decompose these the solution was evaporated and the residue ignited. This, however, was not the source of error, which lay in the incomplete oxidation of the phosphorus to phosphoric anhydride. In the solution of phosphoric iron in nitric acid a considerable proportion of the phosphorus is not converted into phosphoric acid, the oxidation not proceeding sufficiently far, a somewhat large percentage of phosphorous acid being formed, which is not further oxidised by nitric acid. In this form the phosphorus is not precipitated by molybdate; hence the error into which the earlier analysts fell. In igniting the iron nitrate to destroy the supposed organic material, the real source of error was inadvertently also overcome. This method is, however, a lengthy one. The best oxidising agent to employ is potassium permanganate, which comes into the market in a pure form. This cannot be said for hydrogen peroxide, which, in addition, frequently contains much phosphoric acid. Chromic acid, even at a boiling heat, is not a sufficiently strong oxidising agent, a point the author has experimentally determined. The addition of permanganate leads to the deposition of manganese peroxide, but this can be got rid of by the addition of a few drops of a solution of ferrous sulphate. The author considers the use of oxalic acid or of potassium oxalate for this purpose to be dangerous, as the presence of much oxalic acid prevents the complete precipitation of the iron, while, if a very large quantity is present, the precipitation is completely prevented. The

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 15–17.

observation of Finkener was a most important one—that the soluble silica formed during the solution need not be separated. Emmerton and Jones have stated that if the solution is shaken for five minutes at a temperature of 80° C. the precipitation is complete, and this the author confirms. Even after standing for a further period of twenty-four hours no further precipitate could be observed. In order to avoid the necessity for the tedious weighing of the precipitate, many volumetric methods, to which the author refers, have been proposed. These relate to the determination of the molybdic acid, twenty-four molecules of which in the precipitate are the equivalent of one molecule of phosphorus; but the results do not appear as yet to be altogether concordant. Van der Pforten has stated that zinc reduces molybdic acid completely to oxide, while Emmerton states that the result is a mixture of oxide and acid, with the formula $Mo_{12}O_{19}$. Still this difference is not so great as to lead to very important differences in the analysis of a steel. The ammoniacal solution of the molybdate is acidulated, reduced with zinc, and then titrated with permanganate.

The Determination of Sulphur.—Babbitt * describes the Wiborg method of determining sulphur in iron and steel by the generation of sulphuretted hydrogen, which is then caused to colour cloth soaked in a solution of cadmium.

Clymer † gives some determinations of sulphur by several chemists using the aqua regia method, and ascribes the differences to errors of manipulation. These may be due to the evaporation in the separation of silica causing a deposition of insoluble basic ferric sulphate, or to the basic sulphate being precipitated from solutions which are too nearly neutral. Neutralisation with ammonia and standing fourteen hours are recommended.

Treadwell ‡ passes the evolved sulphuretted hydrogen through an ammoniacal solution of cadmium chloride. The cadmium solution is then strongly acidified with hydrochloric acid, and titrated at once with iodine solution.

W. Schindler § observes that Meineke has pointed out that when iron is dissolved in hydrochloric acid, the whole of the sulphur is converted into hydrogen sulphide only in the most exceptional instances, but that Hattensaur had come to the opposite conclusion. That being so, the

* *Journal of Analytical and Applied Chemistry*, vol. vi. p. 301.
† *Ibid.*, p. 319.
‡ *Berichte der Deutschen Chemischen Gesellschaft*, vol. xxv. p. 2377.
§ *Zeitschrift für Angewandte Chemie*, through *Chemisches Repertorium*, vol. xvii. p. 5.

author made a series of experiments which proved that if the acid is fairly concentrated the method is a good one, while if a dilute acid is employed the results are not so accurate.

A. Schneider* disputes the statements of Jannasch and Richards relating to the passage of iron salts into the precipitate of barium sulphate deposited from an iron solution. These experimenters consider that a double sulphate of iron and barium is formed, but the author came to the opinion this is the case of a "solid solution," in the sense that Van 't Hoff has employed this term. He finds that no matter how much iron is present, the barium sulphate always contains approximately the same quantity of ferric sulphate, the quantities observed by him in the barium sulphate varying between the narrow limits 1·12 and 1·38 per cent., or, as a general average, 1·24 per cent.

H. L. Payne† considers the easiest method for the determination of sulphur in iron to consist in volatilising the sulphur as sulphuretted hydrogen, collecting it, and determining it by a iodometric method. An easy method for determining the standard of the iodine consists in remembering that every molecule of the permanganate $K_2Mn_2O_8$ is equivalent to 10 I, and that I_2 is again equivalent to Fe_2, or to S. The iodine solution is made by dissolving 10 grammes of potassium iodide in water, adding 15 cubic centimetres of dilute sulphuric acid, and then the calculated quantity of permanganate. After shaking for a while, the reaction is complete, and the solution is then diluted to one litre. The sulphuretted hydrogen resulting from the solution of the iron in the ordinary manner is passed into a solution of caustic potash. The common commercial salt should be used, as that which has been purified in the first instance by treatment with alcohol is not suitable. The absorption of the sulphuretted hydrogen having been effected, a solution of starch, to which some methyl-orange has been added, is introduced, the solution rendered markedly acid with sulphuric acid, and then titrated with the iodine standard solution.

Mr. F. H. Williams‡ gives the results of some experiments on the use of hot hydrochloric acid for the solution of iron in the volumetric determination of sulphur by the iodine method. The results in all cases were higher than when cold acid was used. No sulphur escaped absorption in the first tube containing the sodium hydrate solution. The residues, after acid treatment of the iron, were always found to contain

* *Chemiker Zeitung*, vol. xvi. p. 326.

† *Journal of Analytical and Applied Chemistry*, vol. vi. p. 481.

‡ Paper read before the Chemical Section of the Engineers' Club of Western Pennsylvania, November 22, 1892.

sulphur, but less than when cold acid was used, and the best results were always below those obtained from solution in aqua regia with fusion of the first precipitate of barium sulphate with sodium carbonate.

A series of experimental determinations of sulphur in a sample of pig iron has been instituted by the Crane Iron Company, the analyses having been made by various chemists of repute in the United States and in Germany. The results obtained varied between 0·005 and 0·024 per cent., as shown in the following table: *—

Method.	Percentage Found.
Nitro-hydrochloric acid	0·005
Absorption and oxidation with bromine, and weighing the insoluble residue as barium sulphate	0·008
Absorption and titration with a standard solution of iodine	0·009
Absorption in an alkaline solution of lead nitrate, and weighing as barium sulphate	0·011
Nitro-hydrochloric acid method, allowing the solution to settle for twenty-four hours	0·012
Nitro-hydrochloric acid	0·012
Absorption in potassium permanganate solution, and weighing the $BaSO_4$ precipitate	0·013
Absorption in cadmium solution, and titration with iodine	0·013
Potassium permanganate method, weighing as $BaSO_4$	0·013
Nitro-hydrochloric acid method, neutralising with ammonia, precipitating as $BaSO_4$, and allowing to settle for twenty-four hours	0·013
Absorption in cadmium chloride solution, and titration with iodine	0·015
Absorption and titration with iodine	0·015
Absorption and titration with iodine	0·017
Absorption in potassium permanganate, and weighing as barium sulphate	0·017
Volumetric, no details given	0·019
Absorption with cadmium sulphate, and titration with iodine	0·020
Nitro-hydrochloric acid method	0·021
Absorption in caustic soda solution, and titration with iodine	0·022
Nitro-hydrochloric acid method	0·024

It is evident from these results that no one method possessed marked advantages over the others. The greatest differences are observable in the nitro-hydrochloric acid method. Assuming that the reagents used in this method are perfectly pure, the chief causes of error are the following:—(1.) Evaporating too far before filtering off the silica and graphite, leading as this does to the formation of basic iron salts, which retain some sulphur, and are insoluble in dilute acid. (2.) The precipitation of the barium sulphate in too acid a solution. This delays the formation of the precipitate very considerably, and too low a result is probable unless the solution is allowed to stand from twelve to fourteen hours

* *Journal of Analytical and Applied Chemistry*, vol. vi. pp. 318-320.

before being filtered. (3.) Precipitating the barium sulphate in too neutral a solution, with the result that some of the iron comes down with the barium sulphate precipitate. These difficulties can all be readily avoided. The solution should not be evaporated to less than 10 cubic centimetres, and any large excess of free acid can be neutralised afterwards with ammonia before precipitating the barium sulphate, as this is almost quite insoluble in ammonium chloride.

The Determination of Silicon.—H. Rubricius* discusses the determination of silicon in pig iron. He observes that it is customary in effecting this determination to evaporate the hydrochloric solution of the iron to dryness, then to take up with hydrochloric acid, dilute, filter, fuse the residue with sodium carbonate with some nitre added at intervals, then to again evaporate and take up with hydrochloric acid, filter, ignite, and weigh the silica.

This lengthy method the author considers unnecessary, believing that the original hydrochloric solution of the iron can be filtered direct, as by using only exactly the quantity of acid that is required to effect the solution of the iron, the quantity of silica that passes into the solution is extremely minute. The solution being filtered, the residue consists mainly of silica and carbon. This the author burns before the blowpipe, using a little nitrate at intervals, until the whole of the carbon has been burnt away. Care must, however, be taken to keep the lid on the crucible. By using a very concentrated solution of ammonium chloride as a solvent, but a very small quantity of silica passes into solution. Solutions of the chloride, which, on the other hand, are of a less degree of concentration, dissolve much larger quantities of the silica. To dissolve the pig iron, from 5 to 6 c.c. of hydrochloric acid of the specific gravity 1·15 is required for every gramme of iron taken. The solution is diluted to 200 c.c., and then filtered. The ammonium chloride solution employed is one of 40 per cent. strength. The method gives results which are accurate to the second place of decimals in the percentage of the silicon.

Mr. C. Platt† recommends a modification of the process of analysing ferro-silicon described by Hogg. The nitro-hydrochloric solution is evaporated to a syrup, and sulphuric acid containing dissolved sulphuric anhydride is added to render the silicon insoluble, and to convert the iron into sulphate.

* *Chemiker Zeitung*, vol. xvii. p. 101.
† *Engineering and Mining Journal*, vol. lv. p. 195.

The Determination of Chromium.—Dr. J. Clark * discusses the methods of determining chromium in steel as given by Galbraith, by Arnold and Hardie, and by Hogg,† and in addition to the methods previously proposed by him,‡ gives two other methods more especially applicable for substances readily soluble in acid. In the first of these the chromium is concentrated as phosphate. From 2 to 5 grammes of the sample is dissolved in dilute hydrochloric acid, and ammonia is added to the solution until a slight permanent precipitate is produced. A slight excess, about one gramme, of sodium phosphate is added, and about twice that amount of sodium hyposulphite or sulphite, preferably the latter, to avoid precipitation of free sulphur. After boiling for ten minutes, the precipitate is filtered off, washed, dried, and ignited at a low heat, not sufficient to agglomerate it. It is then mixed with eight times its weight of finely pulverised magnesia and caustic soda in the proportion of 2 to 3, and heated for half an hour over a low Bunsen flame. The residue is extracted with water, the manganese removed by peroxide of hydrogen, and the solution titrated with ferrous ammonium sulphate. The insoluble residue may require re-fusing. By the second method the chromium is precipitated as a basic sulphite instead of phosphate. Excess of sodium sulphite is harmless as long as no ammonium salts are present. The hydrochloric acid solution of the steel is neutralised by sodium carbonate, and is boiled with slight excess of the sulphite until sulphurous fumes cease to be evolved. The basic sulphite of chromium is then thrown down with some iron and can be readily filtered. It is treated as the phosphate above. Some experiments are given to show the exactitude of the method.

G. Giorgis § describes a method for the determination of chromium founded upon the formation of potassium chromate and hydrated manganese sesquioxide on adding a solution of potassium permanganate to a solution of sesquioxide of chromium in potassium hydrate. The steel is dissolved in nitric and hydrochloric acid, made just alkaline with sodium hydrate, and treated with hot potassium permanganate until the solution becomes red. After cooling and filtering, the solution is acidified with sulphuric acid, reduced by sulphurous anhydride, concentrated, and the chromium is then determined volumetrically by Donath's or some other method.

* *Journal of the Society of Chemical Industry*, vol. xii. pp. 340–341.
† *Journal of the Iron and Steel Institute*, 1892, No. II., p. 516.
‡ *Ibid.*, 1892, No. II., p. 516.
§ *Atti del Accademia dei Lincei; Nature*, vol. xlvii. pp. 397–398.

A method described by A. Perrault* depends upon the reaction which takes place between chromic acid and hydroxyl, accompanied as it is by a blue coloration. The chromium compound is brought into dilute solution, and about 500 cubic centimetres of it is heated to the boiling-point; hydroxyl is then added until the grey colour formed has completely disappeared, and a sufficient quantity of ammonia is added, the chromic oxide having thus been converted into chromic acid. The solution is then boiled for another ten minutes. At first the solution is green, but then it becomes bright yellow and quite clear, and contains the chromium as ammonium chromate. It is allowed to cool, diluted to one-half litre, and 50 cubic centimetres taken for the analysis.

The hydrogen peroxide used is the commercial one diluted with ten times its volume of water. The standard bichromate also employed contains 37 grammes in one litre. In standardising, 3 cubic centimetres of the bichromate solution, containing 0·111 gramme of the salt, is diluted to one litre, and 50 cubic centimetres of this solution is neutralised with dilute ammonia, and then 1·5 cubic centimetre of 10 per cent. hydrochloric acid is added to the solution. The hydrogen peroxide is then run in from a burette until it ceases to give a blue colour with the bichromate.

In converting the chromic oxide into chromate, as stated above, if on acidulating the cooled solution a blue coloration is still observable, ammonia must be again added and the solution boiled with hydroxyl as before.

The Determination of Aluminium.—H. von Jüptner† describes the determination of aluminium in ferro-aluminium. This method consists in dissolving the sample in sulphuric or hydrochloric acid, separating the silica in the ordinary way, precipitating in a portion of the solution the alumina, the ferric oxide, and the phosphorus by means of ammonia, and titrating the iron in a second portion of the solution. The percentage of ferric oxide is then deducted from the weight of the two oxides; the phosphoric acid also present is determined in a third portion, and the weight of the alumina is obtained by difference. A sample of commercial ferro-aluminium examined by the author contained 12·64 per cent. of aluminium. The method above described may be controlled by another in use at the Aluminium Works at Neuhausen. In this 5 grammes of the alloy is dissolved in sulphuric acid, evaporated to

* *Moniteur Scientifique*, 4th Series, vol. vi. p. 722.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 110-112.

dryness, taken up with sulphuric acid, and diluted to 300 cubic centimetres. It is then filtered through a folded filter, 100 cubic centimetres, reduced with iron wire, neutralised with sodium carbonate, and then, to convert the iron into ferrocyanide, the solution is poured into a boiling mixture of potassium cyanide and caustic potash. The precipitate of ferric hydrate is filtered off, the filtrate diluted to 500 cubic centimetres, filtered again, and then 300 cubic centimetres are treated with ammonium nitrate in a porcelain dish, using one and a half times the weight of the salt, as compared with that of the caustic potash used with the cyanide. On heating for an hour, the alumina settles out and can be filtered, washed, and weighed.

For the determination of aluminium in steel, P. Rozycki * places from 0·2 to 2 grammes of the iron in the form of very thin foil in a platinum boat, and heats to redness in a current of oxygen. When the oxidation is complete, the current of oxygen is replaced by one of hydrochloric acid gas. The iron is volatilised, leaving alumina and silica in the residue. This may be treated with hydrochloric acid to dissolve out the silica, and the alumina may then be ignited and weighed.

The Determination of Nickel and Cobalt.—The analysis of nickel and nickeliferous compounds generally is dealt with by Mr. S. H. Emmens,† the various processes being given in tabular form. According to him, none of the published methods are strictly accurate, as there is risk of nickel being carried down with the ferric hydrate, and lost in precipitation methods; neither can electrolytic methods be relied upon. The distinguishing feature of the method proposed is the boiling of the precipitated ferric hydrate with a small quantity of hydrochloric or sulphuric acid. From thermo-chemical data it is shown that the nickel will pass into solution in preference to the iron. The small amount of iron in solution is then reprecipitated by ammonia in presence of ammonium chloride, and after filtration and evaporation to small bulk, the nickel and cobalt are thrown down by sodium hydrate, and the precipitate is then dissolved in hydrochloric acid. The solution is made alkaline with ammonia, and electrolysed to determine these two metals.

M. Syssoyeff ‡ describes a gas volumetric method for the determination of nickel. This depends on the fact that Ni_2O_3 and H_2O_2 reduce each other according to the reaction :—

$$Ni_2O_3 + H_2O_2 = 2NiO + H_2O + O_2.$$

* *Moniteur Scientifique*, 4th Series, vol. vi. p. 815.

† *Engineering and Mining Journal*, vol. liv. pp. 510-511.

‡ *Moniteur Scientifique*, 4th Series, vol. vi. p. 865.

The Ni_2O_3 is produced by treating the solution of the nickel salt to which potassium cyanide has been added by a current of chlorine, the whole of the nickel being then deposited in the form of Ni_2O_3. The quantity of oxygen produced by the reaction between the hydrogen peroxide and the Ni_2O_3, is determined by ordinary volumetric analysis.

If iron is present, the nickel may be separated from it by Mohr's method. Care being taken to avoid any chance of oxidation, the sulphuric acid solution is precipitated by sodium carbonate, and the precipitate produced is redissolved in an excess of the precipitant. The clear solution is then treated as mentioned above with potassium cyanide. Using an excess, the $Ni(CN)_2$ that is in the first instance precipitated is redissolved with the formation of the compound $K_2Ni(CN)_4$. To this solution caustic potash is added, and chlorine being passed through, all the nickel is thrown down as Ni_2O_3 :—

$$2K_2Ni(CN)_4 + 3KClO + 6KCl_2 = 7KCl + 8CNCl + Ni_2O_3.$$

The whole of the iron that may have been present remains in the solution in the form of potassium ferricyanide.

Professor H. Wedding * states that three samples of commercial nickel, each weighing 66 lbs., were cast into bars, and on analysis were found to contain :—

Number.	Ni.	Co.	Fe.	Cu.	Si.	(SiO_2).	C.	S.
1	97·87	1·45	0·45	0·10	0·19	...	trace	0·05
2	97·90	1·25	0·50	0·07	...	0·19	,,	trace
3	98·21	1·19	0·25	0·07	...	0·24	,,	,,

It was found that a little slag was always present in the nickel, although considerable precaution was taken when casting. When no magnesium has been added, the nickel is always porous, irregular in character, and cannot well be hammered out. To render it useful, an addition of magnesium must be made. Aluminium cannot replace magnesium for this purpose.

The Determination of Arsenic.—F. Neher † points out that arsenic may be separated from antimony, lead, bismuth, &c., in the following manner :—If to a solution of an arsenate much hydrochloric acid is

* *Verhandlungen des Vereines zur Beförderung des Gewerbefleisses*, 1893, p. 65.

† *Zeitschrift für Analytische Chemie*, vol. xxxii. p. 45.

added, and a rapid current of sulphuretted hydrogen is passed through the solution, the solution begins to become discoloured after about thirty seconds. A white precipitate forms in the first instance, which soon becomes yellow, and within an hour and a half the whole of the arsenic has been deposited as the penta-sulphide. The hydrochloric acid must be present in the quantity of at least two parts of concentrated acid to one of water, and the solution must not be heated, or else some of the arsenic will distil off. The acid should be added gradually. The author believes that in the first instance a higher chloride of arsenic is formed, and that at higher temperatures this escapes in the form of tri-chloride. The precipitate obtained in this manner is filtered into a Gooch crucible, washed with water, and then with hot alcohol. It is next dried at 100°, and then weighed. If in the original strongly acid solution antimony, bismuth, lead, or cadmium was present, it will remain in solution, but it is advisable to pass a current of air through the solution after the deposition of the arsenic to drive out the sulphuretted hydrogen before washing the precipitate with hydrochloric acid. If tin or copper is present, it passes, in part, into the arsenic precipitate.

II.—*ANALYSIS OF IRON ORE AND SLAG.*

The Determination of Iron.—E. Nihoul * describes a process for the estimation of iron in its ores which depends on the volumetric determination of iodine liberated from potassium iodide by ferric salts in their reduction to ferrous salts. From 0·3 to 0·5 gramme of the mineral is placed in a retort with 25 cubic centimetres of concentrated hydrochloric acid and heated. A current of gaseous hydrochloric acid is preferably passed until solution is complete. The iron is peroxidised by chlorate or potassium permanganate, and hydrochloric acid is passed into the boiling solution until chlorine ceases to be evolved. The retort is then connected to a condenser, and a slight excess of potassium iodide in solution is added, and the iodine liberated by the reduction of the ferric salts is distilled over in a current of carbonic anhydride into the condenser. From there it is collected and titrated with sodium hyposulphite. One part of iodine corresponds to 0·4416 of iron. If the iron is all present in the ferric state, the iodide may be added in the retort at first to aid solution.

* *Revue Universelle des Mines*, vol. xxi. pp. 58–64.

L. Storch * suggests the use of copper turnings as the reducing agent for ferric solutions when the iron is to be determined by permanganate. The solution becomes in the first place yellowish green, and finally blue. The blue solution is diluted and titrated, the end of the reaction being observable by the blue colour turning from one of a greenish hue to a violet.

Ferric oxide which has been heated to redness is generally rendered soluble by fusion with potassium hydrogen sulphate. The author employs instead sulphuric acid of 40 per cent. strength, with which the oxide is boiled for half an hour.

J. W. Rothe has described a method † for the separation of iron, which depends on the solubility of ferric chloride in ether. In using this method of separation in ordinary iron and steel analysis, the following points are particularly to be observed :—

(1.) Suspended matter, such as silica, carbon, and filter-paper shreds, must not be present, as they either totally prevent a sharp separation of the ether solution from the hydrochloric solution, or they at least make it much more slow.

(2.) The acid solution must contain the whole of the iron in the ferric form.

(3.) An excess of chlorine, nitric acid, and other reagents which decompose ether, must as far as possible be avoided.

(4.) The percentage contents in hydrochloric acid must be sufficiently large to ensure the residual ethereous hydrochloric acid being a mixture of ether and hydrochloric acid which contains at least 21 or 22 per cent. of hydrochloric acid (specific gravity, 1·100 to 1·105 at 19° C.).

C. Luckow ‡ discusses the precipitation of the various metals by the aid of potassium ferrocyanide and potassium ferricyanide. In the first place, all those metals which may be precipitated by one or other of these salts can be separated from those which cannot be so thrown down. In addition to the alkalies, these latter include, in fairly dilute solutions, calcium, barium, strontium, aluminium, chromium, and arsenic. Magnesium, even in dilute solution, is in part precipitated by the ferro salt, but it is not thrown down by the ferricyanide even when the solution is a concentrated one. Many metals are precipitated by ferricyanide, but the following are not :—Fe, Mn, U, Pb, Hg, and Sn, in solutions of their higher oxides. In these solutions they can consequently be

* *Berichte der Oesterreichischen Gesellschaft zür Förderung der Chemischen Industrie*, vol. xv. p. 9.

† *Journal of the Iron and Steel Institute*, 1892, No. II., p. 510.

‡ *Chemiker Zeitung*, vol. xvi. p. 1428.

separated from Zn, Ni, Co, Cu, Bi, and Ca. Lead can be best separated from Zn, Cu, and Ag from solutions which contain small quantities of nitric or acetic acid. If only one other metal, in addition to the lead, is present, this is determined by the aid of potassium ferricyanide, while in another portion of the solution both metals are precipitated by ferrocyanide. If in both cases the solutions used contain one-fortieth part of a molecule of the salt to the litre, then all that is necessary is to subtract the cubic centimetres of solution used in the first case from those used in the second, in order to determine the lead by difference. A table is given showing the precipitates produced by ferrocyanide and ferricyanide in different solutions.

The Determination of Manganese.—A. H. Low * dissolves 0·5 gramme of the ore in a 16-oz. flask with from 5 to 10 cubic centimetres of hydrochloric acid or aqua regia, and boils until the free acid is nearly gone. He then dilutes with hot water and adds an excess of zinc oxide, boiling to effect the complete neutralisation of the acid. An excess of bromine solution is then added—about 25 cubic centimetres, but never more than 50 cubic centimetres—and the whole is boiled until the excess has been expelled, red fumes ceasing to appear. The precipitate is filtered through a 5-inch filter, the washed precipitate, together with the filter-paper, being treated with 50 cubic centimetres of a 10 per cent. sulphuric acid solution. Into the solution, &c., so obtained a standard solution is run from a burette. This is a solution of 11·46 grammes of oxalic acid in a litre of water, standardised by a 10 per cent. normal solution of potassium permanganate in the presence of hot dilute sulphuric acid.

An excess of the oxalic acid having been judged to have been run into the precipitate from the ore made in the manner above described, the mixture is heated to boiling, and more oxalic acid added, if necessary, to effect the complete solution of the precipitate. The whole is then diluted with hot water, and the excess of oxalic acid titrated with the standard permanganate solution. The number of cubic centimetres actually consumed by the MnO_2 is thus arrived at, and the whole analysis completed in about twenty minutes. None of the ordinary constituents of ores interfere with the method. The oxalic acid used is of such a strength that 1 cubic centimetre equals about 1 per cent. of manganese.

* *Journal of Analytical and Applied Chemistry*, vol. vi. No. 12; *Chemical News*, vol. lxvii. p. 162.

The Determination of Phosphorus and Arsenic.—Mr. J. Pattinson and Mr. H. S. Pattinson * have modified the usual process for determining arsenic and phosphorus in iron and manganese ores, with the result of considerably shortening the time required. The modifications are:—(1.) The reduction of the ferric-chloride solution with sodium thiosulphate (hyposulphite); (2.) the precipitation of the arsenic with zinc sulphide; and (3.) the precipitation of the phosphorus as ferric phosphate with calcium carbonate. Three grammes of ore is dissolved in hydrochloric acid, and the silica is separated in the usual way. The ferric chloride is then reduced by adding the necessary quantity of a solution of 500 grammes of sodium thiosulphate in a litre of water, which is determined by the absence of a violet coloration. The solution should then measure 50 to 60 cubic centimetres, and it is boiled to separate sulphurous anhydride. Five cubic centimetres of strong hydrochloric acid is added after cooling, together with 0·1 gramme of powdered zinc sulphide. The precipitated arsenic trisulphide, together with the silica, is filtered off. Lead sulphide is removed by washing with warm dilute hydrochloric acid. The filtrate is boiled to expel sulphuretted hydrogen, diluted to 200 to 250 cubic centimetres, and sufficient ferric chloride is added to combine with the phosphorus. Precipitated calcium carbonate is now used to throw down the ferric phosphate at a temperature of 60° to 70° C., and the precipitate then filters readily. The arsenic is determined by the magnesia mixture method. The various precautions given prevent the precipitation of large amounts of sulphur.

Analysis of Basic Slag.—G. Mancuso-Lima † advocates the following method of estimating phosphoric anhydride in basic Bessemer slag:—Two grammes of the finely powdered slag is placed in a flat dish, and treated with 25 cubic centimetres of sulphuric acid diluted with half its volume of water. The pasty mass thus formed is left for two hours, treated with warm water, filtered, and washed. Milk of lime is then added, the whole shaken, and, when alkaline, heated for half an hour on a water-bath, and treated with nitric acid until the lime precipitate is redissolved. It is then allowed to cool and filtered, the solution being precipitated with ammonium molybdate in the usual manner. This method was compared with three other methods in vogue in Italy. The results were all very similar, but the author prefers his method, as being quicker.

* *Journal of the Society of Chemical Industry*, vol. xii. pp. 119–121.
† *Le Stazione Speriment. Agric. Ital.*, vol. xxi. pp. 225–228.

D. Martelli,* however, has compared Mancuso-Lima's method with the usual Italian methods and with that described by König, † and concludes that König's method is the best, as effecting a saving of time and of reagents.

Messrs. C. Arnold and K. Wedemeyer ‡ discuss the method for the determination of phosphoric anhydride in basic slag described by M. Spica.§ The authors are of opinion that the method is for works' laboratories both too long and too costly, and that it is not easy to get accurate results by its aid.

III.—*FUEL ANALYSIS.*

The Analysis of Fuel.—H. von Jüptner ‖ observes that, in view of the very variable composition of different portions of one and the same fuel, it is a difficult matter to obtain a small sample which shall really represent the average composition of the fuel. He therefore abandons the ordinary method, in which one-gramme samples are burnt, and adopts instead the combustion of a much larger quantity in a furnace of special design. The percentage of hygroscopic water can be determined in the ordinary way, as very large samples can be used, and since the percentage of hygroscopic water in a fuel does not vary very greatly under similar conditions. Similarly, too, the percentage of ash may either be determined as usual with small samples, or it is determined when making the combustion experiment with the larger sample. In this latter case a careful sample must be taken from the ash residues, and this must be completely incinerated, with a view to ascertain the amount of unconsumed carbon remaining in it. The loss of weight may be considered as being wholly due to carbon. That portion of the carbon which is deposited in the form of lampblack is, as a rule, so small in weight that it may be neglected, or, if it is desired to determine it, collected in the ordinary way. The only remaining portion of the fuel which requires determination is that which escapes in gaseous form—the carbon, the "disposable" hydrogen, and the so-called chemically combined water. It is easy enough to determine the ratio borne

* *Le Stazione Speriment. Agric. Ital.*, vol. xxi. pp. 453–455.

† *Untersuchung landwirtschäftlicher und gewerbewichtiger Stoffe.* Berlin, 1891, p. 178.

‡ *Zeitschrift für angewandte Chemie*, 1892, p. 603.

§ *Journal of the Iron and Steel Institute*, 1892, No. II., p. 525.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 84–87 and 96–100.

by the disposable hydrogen to the carbon, if the composition of the products of combustion are accurately known—a matter accompanied by no difficulty, provided care has been taken to ensure an average sample by taking the sample during a sufficiently lengthened period of the com bustion. To determine this ratio, the gaseous products, expressed in volumes, should be subdivided into their elements—C as CO_2, C as CO, and C as CH_4, a portion of the disposable hydrogen being in the first instance determined as free hydrogen and as methane, the combustion of the fuel being assumed to be incomplete. The total quantity of oxygen from the air being known from the percentage of nitrogen, the remainder from the fuel is easily calculated. So, too, with the other elements. The volume of the carbon vapour present can be ascertained from those of the carbon compounds existing in the gas mixture. The proportion borne by the carbon so gasified to the disposable hydrogen can then be found in a manner which the author indicates. He deals at length with the determination of the various constituents of fuel. With an experimental furnace, especially constructed so as to admit of the combustion of a large quantity of the fuel, a considerable degree of accuracy may be attained.

The Determination of Ash in Oils. — In the combustion of lubricating oils, the large quantity of smoke formed renders the combustion disagreeable, and the coke that is left is hard to burn. A. Stepanoff* states that the method in use at Baku consists in placing the oil in a platinum dish, covering this with a glass hood connected with a Liebig cooler, and then heating with a burner until the bottom of the dish is red-hot. A further portion of oil is then added and heated as before, until from 200 to 300 grammes have been treated. The last traces of oil are then driven off, and the residual coke burnt in a current of oxygen or before the blow-pipe.

IV.—*GAS ANALYSIS.*

Gas Analysis in Ironworks. — Messrs. W. Macfarlane and P. Caldwell† describe a form of apparatus for gas analysis arranged by

* *Zap. Imp. Russk. Tech. Obszcz.*, vol. xxvi. p. 27; *Chemisches Repertorium*, vol. xvi. p. 348.

† Reprints from the *Journal of the West of Scotland Iron and Steel Institute.* Paper read November 11, 1892.

them to be simple enough for ordinary works' routine, and to be capable of being used for exact measurements. A tube and reservoir is used for regulating the pressure, and the measuring and pressure tubes are set in a cold-water tank. A modified form of bulb, as in Hempel's apparatus, is used, and shaped so that the gas can bubble through the liquid, and the bulbs are placed horizontally. A rocking motion is given to the apparatus. Friedrich's patent stopcock is used. An illustration of the apparatus is given, and several slight modifications were proposed in the discussion.

STATISTICS.

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I.—*UNITED KINGDOM.*

Mineral Statistics. — According to the official report of Her Majesty's Inspector of Mines,* the production of coal in the United Kingdom in 1892 amounted to 181,786,871 tons. The production during the previous year was 185,479,126 tons.

The total quantity of iron ore raised was 11,312,675 tons, of which 5,644,486 tons was obtained from mines under the Coal Mines Act, 2,353,706 from mines under the Metalliferous Mines Act, and 3,314,483 tons from open works. The production of manganese ore amounted to 6078 tons.

The production of pig iron in the United Kingdom in 1892 amounted to 6,709,255 tons, the production of the previous year having been 7,406,064 tons. There were 149 works in operation with 741 furnaces, of which 376 were in blast.

Imports and Exports.—According to the Board of Customs returns, the exports from the United Kingdom during 1892 and 1891 were as follows :—

* *Mineral Statistics of the United Kingdom.* London, 1893.

Description.	1892.	1891.
	Tons.	Tons.
Pig iron	767,053	840,055
Bar, angle, bolt, and rod	173,414	217,121
Railroad	468,003	702,247
Wire (except telegraph wire)	47,350	67,516
Tinplates	395,449	448,379
Cast and wrought	319,909	364,903
Old iron	297,236	321,367
Unwrought steel	106,488	111,068
Steel and iron manufactures	149,131	150,452
	15,246	17,038
Totals	2,739,279	3,240,146

The imports into the United Kingdom during the same years were as follows :—

Description.	1892.	1891.
	Tons.	Tons.
Iron ore	3,778,653	3,180,543
Bar, angle, bolt, and rod iron	75,915	77,416
Unwrought steel	7,083	8,436
Girders, beams, and pillars	74,586	74,035
Unenumerated	143,778	155,044

II.—*AUSTRALASIA.*

Mineral Statistics of New Zealand.—In the report on the mining industry of New Zealand, the output of coal for 1891 is given as 668,794 tons, of coke 2544 tons, of hæmatite ore 1 ton, and of manganese ore 1153 tons.

A report by a committee appointed by the New Zealand Legislature on the New Zealand industries has recently appeared. Amongst other subjects, consideration is given to the production of iron in the Colony, and it is recommended that a bonus be given and that the tariff be raised as soon as works are sufficiently advanced. Coal deposits occur over considerable areas, and the production of this mineral is compared with that in New South Wales.

Mineral Statistics of Tasmania.—According to the Colonial Blue Book, the output of coal in Tasmania in 1891 amounted to 45,524 tons, valued at £1 per ton.

III.—*AUSTRIA-HUNGARY.*

Iron Trade Imports and Exports. Dr. M. Caspaar* states that the imports and exports into and from Austria-Hungary in the year 1891 of fuel, iron, and steel were as shown in the following table:—

Description.	Imports.	Exports.
	Tons.	Tons.
Lignite and brown coal . . .	15,174	6,900,255
Coal	3,670,196	714,435
Coke	248,193	73,453
Total iron and steel manufactures .	89,174	45,443
Firebrick	1,830	3,831
Other fire-resisting materials . .	1,443	928

This table shows that, as compared with the imports and exports in the previous year, both the imports and exports of pig iron have considerably diminished. The author also makes a comparative examination of the statistics relating to the three previous years.†

Mining and Metallurgy in Bosnia and Herzegovina.—In the year 1891 a blast-furnace was completed and put into blast at Vares, and a cupola was also erected at the same works. The quantity of manganese ore raised during the year was 8847 tons, of iron ore 7646 tons, of chrome ore 918 tons, of coal 77,266 tons, and the out-turn of pig iron amounted to 987 tons. In all the mines and works there was one fatal and one severe accident.‡

IV.—*BELGIUM.*

Iron Trade Statistics.—According to the final official statistics,§ the production of pig iron in Belgium in 1891 amounted to 684,126 tons. There were 19 works in operation, with 28 furnaces in blast. The production of coal amounted to 19,675,644 tons; the total number of working collieries being 133.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 559–562.
† *Ibid.*, pp. 612–615.
‡ *Ibid.*, p. 591.
§ *Ministère de l'Intérieur et de l'Instruction Publique. Annuaire Statistique de la Belgique*, 1892, vol. xxiii. p. 284.

Imports and Exports.—The following table shows the Belgian iron trade imports and exports for 1892 and 1891 :—

Description.	Imports.		Exports.	
	1892.	1891.	1892.	1891.
	Tons.	Tons.	Tons.	Tons.
Crude cast steel	8,861	6,589	925	973
Steel rails	625	1,164	73,043	60,171
Other steel	7,778	4,480	13,710	17,707
Wrought steel	1,480	941	11,289	8,579
Pig iron	153,105	183,542	18,227	17,002
Scrap iron	24,919	21,939	9,613	6,962
Iron wire	4,796	5,126	2,260	2,693
Iron rails	66	266	15,655	25,804
Iron plates	1,367	1,555	54,522	47,848
Iron, miscellaneous	12,434	12,395	203,171	213,641
Nails	689	738	7,001	9,606
Wrought iron	3,638	3,792	31,226	31,003
Castings	1,312	1,413	23,780	29,146
Rolling stock	1,458	2,193	41,288	45,601
Machinery	14,813	15,973	36,889	38,817
Totals	237,341	262,106	542,599	555,553

The imports of iron ore during 1892 were 1,681,074 tons, against 1,534,276 tons in 1891; the exports 225,029 tons, compared with 192,127 tons.

The imports and exports of coal and coke were as follows :—

Description.	Coal.		Coke.	
	1892.	1891.	1892.	1891.
	Tons	Tons.	Tons.	Tons.
Imports	1,486,667	1,621,065	191,173	140,576
Exports	4,538,118	4,750,232	955,028	933,668

V.—*CANADA.*

Mineral Statistics.—The statistics of mineral production in the dominion of Canada for 1892 are not all yet available.* Mr. E. Gilpin reports that in Nova Scotia the production in 1892 was as follows :—

* *The Mineral Industry*, New York, 1893, p. 518.

	Tons.
Coal	1,942,000
Iron ore	75,000
Manganese ore	111

In Ontario, the production, according to Mr. A. Blue, included 800,000 barrels of petroleum, 2082 tons of nickel ore, and 160,000 dollars' worth of natural gas.

In Quebec, the production of iron ore is given by Mr. J. Obalski at 28,090 tons.

In British Columbia the production of coal, according to Mr. A. Dick, was 826,335 tons, of which 64,579 tons was exported.

The coal production of Alberta or the North-West Territory is estimated to have been 351,338 tons.

Iron Trade Imports.—The imports of iron into Canada are given as follows for 1892:*—

	Tons.
Wrought iron scrap	36,543
Pig iron	68,918
Blooms, muck iron, &c.	3,100
Bar iron	7,500

VI.—*FRANCE.*

Iron and Steel.—The production of pig iron for 1892 is stated to have been as follows:—

Description.	Forge Pig Iron.	Foundry Pig Iron.
	Metric Tons.	Metric Tons.
Coke pig iron	1,602,417	395,424
Charcoal pig iron	10,519	1,774
Mixed brands	...	12,855
Totals	1,612,936	410,053
Totals in 1891	1,497,751	421,434
Increase	115,185	...
Decrease	...	11,381

The total production of pig iron thus amounted to 2,022,989 metric tons, against 1,919,185 tons in 1891.

* *Canadian Manufacturer; Engineering and Mining Journal*, vol. lv. p. 317; *American Manufacturer*, vol. lii. p. 633.

The production of manufactured iron was as follows :—

Description.	1892.	1891.
	Metric Tons.	Metric Tons.
Puddled rails	418	514
Merchant iron, puddled	575,640	560,703
,, ,, charcoal	10,542	11,909
,, ,, obtained by reheating	120,010	124,187
Total merchant iron	706,192	696,799
Plates, puddled	112,086	102,964
,, charcoal	2,019	2,503
,, by reheating	7,453	8,841
Total plates	121,558	114,308
Total production	828,168	811,621

The production of steel was as follows :—

Description.	1892.	1891.
	Metric Tons.	Metric Tons.
Cast steel—		
Rails	231,484	194,162
Bars, blooms, &c.	282,707	272,656
Plates	116,504	111,754
Various steels—		
Puddled or forged steel	12,135	14,332
Cement steel	1,295	1,398
Crucible steel	10,861	10,165
Totals	655,086	604,467
Summary—		
Bars	307,098	298,551
Rails	231,484	194,162
Plates	116,504	111,754
Totals	655,086	604,467

Imports and Exports.—The French iron trade imports and exports during the years 1892 and 1891 were as follows : *—

* *Moniteur des Intérêts Materiels*, vol. xliii. p. 333.

Description.	Imports		Exports.	
	1892.	1891.	1892.	1891.
	Tons.	Tons.	Tons.	Tons.
Coke	1,424,203	1,319,827	55,711	58,421
Iron ore	1,683,758	1,437,536	304,646	298,550
Crude iron of all classes	87,273	56,756	120,755	98,058
Manufactured iron	17,912	13,174	30,010	34,116
Steel	5,255	5,303	9,001	18,079
Totals of iron and steel	110,440	75,233	159,766	150,253

Of iron and steel imported and exported after manufacture, the quantities were as follows:—

Description.	Imports.		Re-exports.	
	1892.	1891.	1892.	1891.
	Tons.	Tons.	Tons.	Tons.
Pig iron:—Forge	28,654	55,186	24,992	56,350
Foundry	34,051	78,350	31,298	40,901
Manufactured iron	21,717	18,688	23,445	17,861
Steel	1,679	2,480	2,249	2,326
Totals	86,101	154,704	81,984	117,438

The French imports and exports of coal and coke for the year 1892, as compared with the previous year, were as follows:—

Description.	Imports.		Exports.	
	1892.	1891.	1892.	1891.
	Tons.	Tons.	Tons.	Tons.
Coal	9,082,506	9,222,073	829,500	820,482
Coke	1,292,453	1,319,827	75,329	58,421

The Iron Ore Deposits of Algiers.—According to the French official returns,* there are two important deposits of iron ore in Algiers. One of these, in the department of Constantine, consists of magnetite,

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 11.

whilst the other, in the department of Oran, consists of a red hæmatite rich in manganese. The chief company working these two deposits is that of Mokta-el-Hadid. This company mined in 1890, from their mines at Beni Saf, in Oran, 345,000 tons of hæmatite of an average value of 7s. 1½d. per ton, whilst the value of each of the 129,000 tons of magnetite raised at the Aïn-Mokra mines, Constantine, was 6s. 9d. Altogether there was raised in Algiers in 1890, 475,000 tons of ore, the quantity exported during the same year being 517,000 tons. The ore raised exceeded that named in the previous year by as much as 123,000 tons, and the quantity exported showed a similar increase of 78,000 tons.

VII.—*GERMANY.*

Iron Trade Statistics.—The official statistical returns show that the production of iron ore, iron, and steel in Germany and Luxemburg was as follows in the years mentioned: *—

Description.	1889.	1890.	1891.
Iron ore, tons	11,002,187	11,406,132	10,657,522
Number of productive mines	720	755	681
,, workpeople employed	37,762	38,837	35,390
,, ironworks	108	108	109
Charcoal pig iron, tons	24,927	24,142	25,548
Coke and mixed fuel pig iron, tons	4,499,631	4,634,310	4,615,619
Workpeople employed	23,985	24,846	24,773
Total blast-furnaces	264	268	270
Active blast-furnaces	213	222	218
Foundry pig iron, tons	610,893	619,008	702,984
Acid and basic Bessemer pig iron, tons	1,965,395	2,135,799	2,337,199
Forge pig iron, tons	1,905,311	1,862,895	1,553,835
Direct castings, tons	29,295	32,812	36,964
Other pig iron castings, tons	989,621	1,027,384	1,028,387
Active foundries	1,119	1,148	1,160
Workpeople	59,437	63,960	62,740
"Weld iron" works	261	255	250
Weld iron and steel manufactures and blooms, tons	1,749,962	1,559,063	1,484,064
"Ingot iron" works	111	115	117
Ingot iron manufactures and ingots, tons	2,095,479	2,232,099	2,562,549
Workpeople	48,371	52,823	57,929
Average value per ton of ingot metal products	£6 13 6	£7 7 4	£6 11 7

The quantity of rails made amounted to 427,899 tons in 1889, 559,746 tons in 1890, and 596,209 tons in 1891. Of wire 183,311

* *Stahl und Eisen*, vol. xiii. pp. 32-34.

tons was made in 1889, 217,264 tons in 1890, and 277,800 tons in 1891. Indeed nearly every ingot metal manufacture shows a marked increase in the period under review.

Production of Pig Iron.—The production of pig iron in Germany during the year 1892 amounted to 4,793,003 tons, as compared with 4,452,019 tons in 1891. This output was composed as follows: *—

Description.	Metric Tons.	Per Cent. of Total Quantity.	
		1892.	1891.
Forge pig iron and spiegeleisen	1,842,167	38·4	39·2
Acid Bessemer pig iron	313,819	6·6	8·7
Basic pig iron	2,006,400	41·8	38·3
Foundry pig iron	630,617	13·2	13·8
Totals	4,793,003	100·0	100·0

These statistics are those collected by the German Iron and Steel Association. The official Government returns give the output of pig iron in 1891 as 4,641,217 tons. The official statistics for 1892 have not appeared.

Imports and Exports.—The iron trade imports into Germany were as follows in the years mentioned: †—

Description.	1891.	1892.
	Metric Tons.	Metric Tons.
Pig iron	244,852	209,306
Scrap	5,164	6,419
Shaped iron	724	281
Rails	15,773	7,186
Bar iron	22,364	21,085
Blooms and ingots	654	440
Sheets and plates	2,711	2,632
Total iron and iron manufactures	329,396	278,457
Iron ore	1,408,025	1,655,843

The iron trade exports from Germany in the year 1892 were as follows, those for 1891 being also shown: ‡—

* *Stahl und Eisen*, vol. xiii. p. 128.
† *Ibid.*, vol. xiii. p. 214.
‡ *Ibid.*, vol. xiii. p. 180.

Description.	1892.	1891.
	Metric Tons.	Metric Tons.
Pig iron	113,391	64,377
Scrap	64,627	59,465
Angle iron	84,055	74,631
Rails	113,712	142,846
Sleepers, &c.	39,558	63,406
Bar iron	199,064	193,253
Blooms and ingots	37,184	42,458
Wire	187,376	167,471
Plates and sheets	58,377	64,575
Total iron and iron manufactures	1,133,676	1,166,043
Total iron ores	2,276,155	1,984,428

The total value of the iron and iron manufactures exported in 1892 amounted to £13,334,450, a total differing by less than £3 from that of the previous year. The value of the iron ore exported in 1892 was £352,800, as compared with £305,200, the value of the ore exported in 1891.

Production of Iron in Saxony.—In the year 1891 pig iron was made at only one works in Saxony, the Königin Marien Works at Cainsdorf. Its production was as follows in the years mentioned :—

Description.	1891.	1890.
	Tons.	Tons.
Foundry pig iron	13,774,995	6,879,985
Forge pig iron	7,693,820	5,581,700
Bessemer pig iron	...	4,693,605
Castings	147,720	112,485
Totals	21,616,535	17,267,775

In 1891, 150 male and 18 female workpeople were employed, and 50,109 tons of ores smelted, together with 15,797 tons of flux.*

VIII.—*INDIA.*

Mineral Statistics.—According to the Return of Mineral Production in India for 1891, the total yield of coal for that year amounted to 2,328,577 tons, valued at £527,610. The production of iron ore was 33,335 tons, valued at £12,865, and that of petroleum 6,136,495 gallons, valued at £31,794.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 640.

IX.—*ITALY.*

Mineral Statistics.—According to the official returns,* the production of minerals in Italy in 1891 was as follows:—

Description.	Production.	Number of Mines.	Number of Workmen.
	Tons.		
Iron ore	216,486	43	2,269
Manganese ore	2,429	5	127
Coal and lignite	289,286	39	2,386
Asphalt	28,180	10	719
Petroleum	1,155	10	251
Graphite	2,415	12	67

During the same year the Italian iron and steel works produced the following amounts:—

Description.	Production.	Number of Works.	Number of Workmen.
	Tons.		
Pig iron	11,930	8	211
Malleable iron	152,668	324	11,395
Steel	75,925		

X.—*JAPAN.*

Mineral Statistics.—The mineral production of Japan in 1890 is stated † to include:—

	Metric Tons.
Coal	2,608,285
Manganese ore	2,571
Graphite	4,529
Pig iron	16,176
Manufactured iron	4,887
Steel	1,173

The production of petroleum amounted to 2,017,116 gallons.

XI.—*RUSSIA.*

Mineral Statistics.—According to the statistics published by S. N. Kulibin,‡ the production of iron ore in Russia in 1890 amounted

* *Statistica Mineraria del Regno d'Italia per l'Anno* 1891. Rome, 1892.

† *The Mineral Industry*, New York, 1893, p. 536.

‡ *Berg- und Hüttenmännische Zeitung*, vol. lii. pp. 83–85.

to 109,622,052 poods (1,769,000 tons), an increase of 9,500,000 poods as compared with 1889. Most of the ore (56,000,000 poods) was obtained from mines in the Ural. The ore was smelted at 146 ironworks with 214 blast-furnaces. The ore smelted amounted to 103,332,243 poods, with some 7,500,000 poods of slags. The yield was as follows:—

Fuel Used.	Poods.	Per Cent.
Charcoal	37,326,643	65·99
Coal	18,278,381	32·32
Mixed fuel	955,050	1·96
Totals	56,560,074	100·00

The mean annual out-turn of a furnace was 264,299 poods (4260 tons).

The production of weld iron amounted to 26,445,545 poods, or 329,166 poods more than that of the previous year. There were 172 works at which weld iron was produced.

Steel was produced at 32 works, the out-turn amounting to 23,102,797 poods, or 73,070,045 poods more than that of the previous year.

Manganese ore was raised at 300 mines, the production amounting to 11,139,701 poods, or 6,500,000 poods more than in the previous year.

There were 336 collieries producing, the output being as follows:

	Poods.
Bituminous coal	321,849,785
Anthracite	36,483,528
Lignite	8,870,732
Total	367,204,045

The production of coke amounted to 18,066,678 poods.

The production of petroleum was 240,380,924 poods, that of asphalt 743,237 poods, and that of graphite 1000 poods.

Petroleum Industry of the Caucasus.—The most important oil-wells occur in the vicinity of the village of Balachanu, about 16 miles from Baku, in a bare plateau 100 feet above the level of the Caspian Sea. At the present time there are upwards of 1000 oil-wells producing, the output being 400,000 poods (6430 tons) per twenty-four hours.

The rapid development of the industry, since the Paris house of Rothschild began to participate in the trade in 1887, is shown by the following statistics:—

Year.	Raw Naphtha.	Petroleum.
	Poods.	Poods.
1887	165,000,000	44,000,000
1891	289,575,400	72,885,331

The consumption of Caucasian petroleum in 1890 amounted to 37,485,000 poods, of which 7,870,000 poods were exported to Great Britain.*

The Russian Iron Industry.—The imports of iron and iron manufactures into Russia have considerably fallen in recent years, owing to the great increase which has taken place in the home industry. The quantity of iron ore raised has been as follows in the years mentioned:—

Year.	In all Russia.	In Russian Poland.
	Tons.	Tons.
1880	448,400	39,120
1887	612,430	60,900
1889	740,050	88,140
1891	953,560	121,900

The quantity of iron made from this ore was as follows:—

Year.	In all Russia.	In Russian Poland.
	Tons.	Tons.
1880	284,700	19,710
1884	362,230	57,310
1889	427,780	66,356
1891	...	72,285

The Ural, Russian Poland, and the south and south-western districts of Russia are the greatest centres of the iron trade. The production of malleable iron in Russia in 1880 was 17,831,000 poods, and in 1889 26,116,000. Full details are not given for the year 1890, but the production will probably exceed that of 1889, though not to any very large extent. The out-turn of steel increased from 18,761,000 poods in 1880 to 22,701,000 poods in 1890. In the previous year the out-turn had fallen to only 15,796,000 poods.

This rapid increase was mainly due to the iron and steel works of Southern Russia, and to the great increase in the demand for rails by

* *Berg- und Hüttenmännische Zeitung*, vol. lii. pp. 61-62.

the Russian railways. Of the various varieties of steel the production of Russia was as follows in 1890 :—

	Poods.
Cement steel	107,888
Puddled steel	223,185
Bessemer steel	4,863,780
Open-hearth steel	10,298,453
Crucible steel	302,446

No details are available as to the production of steel rails in either 1890 or 1891, but the manufacture has been a rapidly increasing one, and the total quantity made in 1889 was 5,394,338 poods.

The imports of foreign pig iron into Russia have steadily diminished since 1883, the year in which the increased duty was established.*

The Coal Industry of Russia.—Considerable progress has of late been made in the coal industry of Russian Poland. Nearly the whole of the coal raised in Russia comes either from this district or from the Donez basin, and the total output has increased from 3,493,510 tons in 1881, to as much as 6,028,110 tons in 1890. In Russian Poland the output has nearly doubled during this interval. The seventeen collieries of the Dabrowa basin in 1891 possessed 173 steam-engines of 10,946 h.p., and they gave employment to 3238 miners, and 8056 other workpeople. The imports of British coal into Odessa in 1889 were 14,828,400 poods, but by 1891 these had fallen to less than half the quantity, 7,052,703 poods, or 113,753 tons. The imports of coal and of coke into Russia in 1891 were respectively 93,837,000 poods and 12,291,000 poods. The exports of coal in the same year were 683,000 poods.†

The output of coal in Poland in 1892 amounted to 2,806,528 tons, an amount that exceeded the production of the previous year by 272,061 tons, or 10·8 per cent. Of the total amount, 80 per cent. was produced by four coal-mining enterprises. The output is expected to increase this year.‡

XII.—*SPAIN.*

Mineral Statistics.—The following statistics relating to the mineral production of Spain are given by Román Oriol :§—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 569.

† *Ibid.*

‡ *Industries*, vol. xiv. p. 267.

§ *Revista Minera*, vol. xliv. p. 1.

Description.	1892.	1891.
	Metric Tons.	Metric Tons.
Coal	1,353,860	1,290,464
Lignite	38,290	30,116
Iron ore	5,436,150	4,822,089

The production of iron and steel is given as follows:—

Description.	1892.	1891.
	Metric Tons.	Metric Tons.
Pig iron	211,436	278,462
Wrought iron	83,181	59,910
Steel	54,915	69,892
Manufactured iron and steel	85,800	104,800

Iron Trade Imports and Exports.—The iron trade imports into Spain during the year 1892 were as follows: *—

	Metric Tons.
Coal	1,688,537
Coke	175,872
Briquettes, &c.	25,682
Raw petroleum	44,656
Pig iron	30,022
Manufactured iron	10,177
Forged steel	31,637

The exports included—

	Metric Tons.
Iron ore	4,773,827
Manganese ore	10,410
Coal	14,390
Pig iron	43,412

Exports of Iron Ore from Bilbao.—Notwithstanding the depression of trade in other districts, the exports of iron ore were considerably greater in 1892 than in the previous year.† The quantity exported in 1892 was as follows:—

To	Metric Tons.
United Kingdom	2,650,753
Germany	766,302
France	390,319
Belgium	75,249
United States	34,164
Other countries	1,757
	3,918,544

* *Revista Minera*, vol. xliv. p. 78.

† *Comité des Forges de France*, Bulletin No. 718.

XIII.—*SWEDEN.*

Mineral Statistics.—According to the official statistics * there was mined in1891 in Sweden 985,255 tons of iron ore, and 2150 tons of lake and bog iron ore was also raised. The respective totals for the preceding year were 940,429 tons and 812 tons. The quantity of pig iron made amounted to 486,680 tons, and of direct castings 4233 tons, as compared with 451,443 tons, and 4660 tons respectively in 1890. In the foundries the castings made amounted to 37,515 tons, an increase of 545 tons on the out-turn of the previous year. The blooms made weighed 224,651 tons, bar iron 280,430 tons, and Bessemer metal 92,985 tons, each of these showing a diminution in the production of about a thousand tons when compared with that of the previous year. On the other hand, there was an increase of over 5000 tons in the out-turn of open-hearth metal, which reached 78,197 tons in the year under mention. Other kinds of steel made weighed only 1592 tons, as compared with 2056 tons in 1890, and iron and steel manufactures 72,438 tons, as compared with 78,998 tons. The nickel ore raised amounted to 483 tons, and the manganese ore to 9080 tons, both showing considerable reductions when compared with the respective outputs in 1890. The graphite raised weighed 16¾ tons.

The production of coal amounted to 2,475,412 hectolitres in 1891, as compared with 2,343,895 in the previous year, and that of fireclay to 1,045,541 hectolitres in 1891, and 978,355 in 1890.

The active blast-furnaces numbered 155, and these were in blast 40,099 days, the average daily out-turn being 12,243 tons. In 1890, 154 furnaces were in blast, their average daily out-turn being slightly less than in 1890, 12·037 tons. The manufacture of iron castings was carried on at 133 works. Blooms and bar iron were made at 165 works, which possessed 489 hearths and other furnaces, the numbers for 1890 being respectively 157 and 445.

The Bessemer works numbered fifteen, while twenty-two works made open-hearth metal. Other kinds of steel were made at eight works. Iron and steel manufactures were made at 145 works. Of the various products, the wire made amounted to 6600 tons.

The most important works were those of Kopparberg, where 21,744 tons of manufactured articles was made. Not one of the other twenty Government works made one-half the quantity that was made at the Kopparberg Works. Scythe-blades were made at these latter works

* *Stahl und Eisen*, vol. xii. p. 1007.

alone, sheets at a number of works, and ordnance only at the Orebro Works.

The total number of workpeople employed at all the mines and metallurgical works of Sweden in 1891 numbered 35,310.

XIV.—*SWITZERLAND.*

Imports and Exports.—The imports into Switzerland in the year 1892 included 9589 metric tons of lignite, 921,805 of coal, 148,027 of briquettes, 7869 tons of charcoal, 40,825 tons of pig iron and scrap, and 90 tons of nickel. The exports comprised 73 tons of briquettes, 3841 of charcoal, 9164 of iron, 3 of nickel, and 1959 of coke. In addition, 4039 tons of oils of various kinds was also imported, as also was 44,230 tons of petroleum and 63,535 tons of coke.*

XV.—*UNITED STATES.*

Production of Pig Iron.—The total production of pig iron in the United States in 1892 was 9,157,000 tons, as compared with 8,279,870 tons in 1891 and 9,202,703 tons in 1890. The Bessemer pig iron made in 1892 amounted to 4,444,041 tons, of foundry and forge pig iron 4,190,606 tons, and of spiegeleisen and ferro-manganese 179,131 tons. The charcoal pig iron made amounted to 537,621 tons in 1892, the bituminous coal and coke metal to 6,822,266 tons, and the anthracite pig iron to 1,797,113 tons, the respective figures for 1891 being 576,964 tons, 5,836,798 tons, and 1,866,108 tons.†

Production of Bessemer Ingots and Rails.—The following table shows the production of Bessemer steel ingots in the United States in 1892, compared with the total production in 1891 :—

States.	1892.	1891.
	Tons.	Tons.
Pennsylvania . . .	2,397,984	2,048,330
Illinois	879,952	605,921
Ohio	409,855	333,666
Other States . . .	480,644	259,500
Totals . .	4,168,435	3,247,417

* *Chemiker Zeitung*, vol. xvii. p. 529.

† *Annual Statistical Report of the American Iron and Steel Association*, 1893, p. 35.

The total production of Bessemer steel ingots in 1890, the year of largest production prior to 1892, was 3,688,871 tons, which was 472,101 tons less than in 1892.

The total production of Bessemer steel rails in 1892, with the exception of the small quantity of rails made by other manufacturers from purchased materials, was 1,458,743 tons, an increase of 219,350 tons over the production in 1891. The following table shows the production in 1892 compared with that of 1891 :—

Rails.

States.	1892.	1891.
	Tons.	Tons.
Pennsylvania	885,652	849,556
Illinois	450,553	364,725
Other States	122,538	25,112
Totals	1,458,743	1,239,393

The production of Bessemer steel rails by the Bessemer steel manufacturers in 1890 was 1,797,489 tons. The production of 1892, while much larger than that of 1891, was 338,746 tons less than that of 1890.*

Production of Iron Ore.—Mr. J. Birkinbine† states that the output of iron ore in the United States has been as follows :—

Locality.	1872.	1885.	1891.
	Tons.	Tons.	Tons.
Marquette Range	948,553	1,430,862	2,482
Menominee Range	...	690,435	1,856,124
Gogebic Range	...	119,590	2,041,754
Vermilion Range	...	227,075	945,105
New Jersey	600,000	330,000	525,612
Cornwall, Pennsylvania	193,317	508,864	663,746
Lake Champlain, New York	350,000	420,000	554,865
Missouri	...	169,162	106,749
Ohio	...	...	104,487
Alabama	...	505,000	1,986,830
Imports of ore	27,000	390,786	912,864

The total quantity of iron ore raised in the United States in 1891 was 14,591,178 tons. The percentages of the different kinds of iron ore

* *Iron Age*, vol. li. p. 800.

† "Mineral Resources of the United States," 1891, with diagrammatic curves; *Iron Age*, vol. l. p. 780.

contained in the total output has been as follows in the years mentioned :—

Description.	1880.	1889.	1890.	1891.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Red hæmatite	31·51	62·38	65·65	63·92
Brown hæmatite	26·96	17·38	15·96	18·90
Magnetite	29·97	17·26	16·03	15·88
Carbonate	11·57	2·98	2·36	1·30

Imports and Exports.—The report of the United States Bureau of Statistics for the year 1892 has recently been issued.* The imports of iron and steel into the United States in the calendar years 1891 and 1892 are stated to have been as follows :—

Description.	1892.	1891.
	Tons.	Tons.
Iron ore	806,585	912,856
Pig iron	70,125	67,179
Scrap iron and steel	29,228	44,434
Bar iron	19,282	18,099
Bars, railway, of iron or steel	347	253
Hoops or band iron	1,011	186
Hoop, band, or scroll iron or steel	725	685
Ingots, blooms, slabs, billets, and bars of steel . .	30,586	34,685
Sheet plate and taggers, iron or steel . . .	26,959	11,882
Tin plates, terne plates, and taggers, tin . . .	268,223	327,899
Wire rods of iron or steel	42,423	46,938
Wire and wire rope	3,831	4,398
Anvils	748	813
Chains	544	448

The exports during the same periods were as follows :—

Description.	1892.	1891.
	Tons.	Tons.
Pig iron	15,427	14,946
Band, hoop, and scroll iron	36	162
Bar iron	963	1,340
Ingots, bars, and rods of steel	205	538
Nails and spikes :—		
Cut	6,816	4,635
Wire, wrought, horseshoe, and others, including tacks	954	847
Plates and sheets :—		
Of iron	259	344
Of steel	202	104
Railroad bars or rails :—		
Of iron	486	160
Of steel	7,496	11,079

* *Iron Age*, vol. li. p. 317.

Condition of the Blast-Furnaces.—The blast-furnaces in blast in the United States at January 1, 1893, were as follows :—

Fuel Used.	Number of Furnaces.	Weekly Capacity.
		Tons.
Anthracite	70	32,772
Coke	138	131,731
Charcoal	38	8,865
Totals	246	173,368

The output of pig iron in the United States during the second half of 1892 was about 4,300,000 tons, or a total of 9,100,000 tons for the whole year. The stocks of pig iron at January 1 were 749,906 tons.*

The Iron Industry of the Southern United States.—Dr. W. M. Sweet † describes the rapid growth made by the iron and steel industry of the Southern States of the American Union during the past decade. He publishes tables showing the present position of the industry and its recent growth.

The Southern blast-furnaces made in 1890 more than 19 per cent. of the total quantity of pig iron made in the United States, but in 1880 this percentage was only 9.

The Manufacture of Tin Plate.—The output of tin and terne plates in the United States during the fiscal year ending September 30, 1892, is stated by Mr. Ira Aejer ‡ to have amounted to 13,646,719 lbs., of which no less than 10,952,725 lbs. was made within the period July 1, 1892, to September 30 of the same year. On September 30 there were thirty-two active works, besides others in course of construction or enlargement, belonging in all to forty-six manufacturing concerns. The wages paid in the United States are stated to compare as follows with those paid in the United Kingdom :—

* *Iron Age*, vol. li. p. 82.

† *Census Bulletin*, No. 347.

‡ Official Report to the United States Treasury ; *Iron Age*, vol. l. p. 836.

Workmen.	United Kingdom. (Per Box.)	United States. (Per Box.)
	Cents.	Cents.
Roller	7	22
Heater	5 1/10	14
Behinder	3 1/2	7
Doubler	5 1/10	15
Shearman	2 1/2	9
Two openers	*48	...
Scrap boy	†36	†75
Picklers	2 1/2	5
Cold rolling	1 1/2	3 1/4
Annealing	2 1/10	4 1/2
Tinman	6	12
Washman	6	12
Riser	2	4
Catcher	1 1/2	2 1/2
Three rubbers / Three dusters	1 1/4	2 1/2

It will be seen that the average of wages paid in the rolling-mill work in the United States is from two to three times as great as in the United Kingdom, and in the finishing or tinning department about twice as great.

The Connellsville Coke Region.—The output of coke in the coke district of the Connellsville region in 1892 exceeded that of any previous year, with the exception of 1890. The quantity of coke made amounted to 6,167,348 tons, valued at 11,179,961 dollars. At the close of the year the ovens at work numbered 13,246.‡

Lake Superior Iron Ore.—The total quantity of iron ore shipped from the various districts of the Lake Superior Region in 1892 was as follows :—

Range.	Tons.
Gogebic	2,973,993
Marquette	2,666,856
Menominee	2,261,499
Vermilion	1,167,650
Mesabi	4,245
Total	9,074,243

During the preceding year the shipments amounted to 9,003,701 tons.§

* In the United States shearmen pay openers.
† Per day.
‡ *Iron Age*, vol. li. p. 62.
§ *Ibid.*, vol. li. p. 133.

The Consumption of Iron on a Railway.—Details are published* showing the consumption of metal on the line of the Illinois Central Railway. The maximum yearly consumption of rails since 1887 was in the year 1889–90, when, with 2875 miles of track laid, the consumption of rails amounted to 23,999 tons. In the following year, with the same length of line, the rails laid weighed 14,190 tons; and in 1891–92 the consumption amounted to 15,881 tons, the length of the line being then 2888 miles. The greater portion of the railway is equipped with 60-lb. steel rails, though heavier rails are gradually being introduced. The coal used by this railway in 1892 was 867,109 tons, and the new wheels and axles used in repairs were respectively 12,489 and 2490.

Cost of Making Pig Iron in Virginia.—The cost of making pig iron at the Rockbridge Furnace, Virginia, is stated to be as follows:—

	Dollars.
Coke	3·78
Ore	2·53
Limestone	0·50
Salaries and labour	1·35
Incidental expenses	0·60
Total	8·76

This plant was erected in 1884, and was at first a failure.†

Iron Industry of the Schuylkill Valley.—In his presidential address at the Schuylkill Valley meeting of the American Institute of Mining Engineers, Mr. J. Birkinbine ‡ traced the early history of the mining and metallurgical industries of Pennsylvania. The earliest written record of the manufacture of iron in that State is the following verse from a poem published in 1692:—

> "A certain place here is, where some begun
> To try some Mettle, and have made it run;
> Wherein was Iron absolutely found,
> And once was known about some Forty Pound."

In 1731 pig iron is reported to have been sold in large quantities at the Coalbrookdale Furnace, Pennsylvania, at £5, 10s. per ton, local cur-

* *Iron Age*, vol. l. p. 922.

† *Ibid.*, vol. li. p. 375.

‡ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

rency, equivalent to £3 in gold. The earlier furnaces and forges were enumerated by the author, and he pointed out that though the existence of anthracite coal in Pennsylvania was known before 1800, it was not until 1820 that any considerable quantity was shipped. It is hard to realise that within seventy years the production of these coalfields has come to exceed an annual output of 40,000,000 tons. The resources of the Schuylkill Valley appear to be far beyond danger of exhaustion, even by its annual production, approximating 12,000,000 tons of anthracite, 600,000 tons of pig iron, and a greater amount of rolled iron and steel, much of which is converted locally into machinery, bridges, roofs, stoves, and hardware.

XVI.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended :—

Country.	Year.	Production in Tons.
United Kingdom	1892	181,786,871
Australasia—		
New South Wales	1891	4,037,929
New Zealand	1891	668,794
Queensland	1891	271,603
Tasmania	1891	45,524
Victoria	1891	22,834
Austria, coal	1891	9,192,885
,, lignite	1891	16,183,076
Hungary, coal	1891	994,812
,, lignite	1890	2,249,098
Belgium	1892	19,591,908
Cape of Good Hope	1891	27,677
Canada	1891	3,087,110
France	1892	26,548,860
Germany, coal	1891	73,715,653
,, lignite	1891	20,536,625
India	1891	2,328,577
Italy, lignite	1891	216,486
Japan	1890	2,608,285
Natal	1891	126,444
Russia	1890	6,118,560
Spain	1892	1,353,860
Sweden	1891	347,000
United States	1890	153,365,495

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1892	6,709,255
Austria	1891	617,145
Hungary	1890	285,102
Belgium	1892	768,321
Canada	1891	21,331
France	1892	2,022,989
Germany	1892	4,793,003
Italy	1891	11,930
Japan	1890	16,176
Russia	1891	936,000
Spain	1892	211,436
Sweden	1891	490,913
United States	1892	9,157,000

The World's Iron Trade.—Dr. H. Wedding * compares the progress of the iron trade in the chief iron-producing countries during the past twenty years. The production of iron ore he tabulates as follows:—

Country.	1870.	1880.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.
North America	3,081,000	7,234,000	16,293,000
Great Britain	16,596,000	18,314,000	14,001,000
Germany	4,970,000	7,238,000	11,406,000
Spain	...	3,503,000	5,789,000
France	...	2,874,000	2,579,000

Thus, while the production of Great Britain was in 1890 only 84 per cent. of what it was in 1870, or rather in 1871, that of the United States was more than five times, and that of Germany more than twice as large as it was in 1870. Spain and France, too, show large increases in the last decennium. In the year 1891 both the United States and Great Britain, and Germany also, showed a diminished output of ore.

The imports of iron ore by the different countries are referred to, the author showing that the percentage borne by the tonnage of imported ores to that of the ores raised at home was as follows in the countries mentioned :—

	Per Cent.
United States	7·8
Germany	13·3
United Kingdom	32·5
France	62·4

Both the United States, Germany, and Spain export more ore than they import, but the imports of ore into France and the United Kingdom

* *Stahl und Eisen*, vol. xiii. pp. 230–236.

largely exceed the exports. In Europe the value of iron ore has greatly diminished in the past twenty years, and the districts which are now the greatest producers, both in Europe and in the United States, were mostly either unknown or but relatively small producers in 1870; the more important iron ore fields at the present time being those of Lake Superior, Cleveland, Luxemburg, and Lorraine, including the adjacent portions of France, and the north of Spain. These districts produced, in 1890, 48·7 per cent. of the total world's output of iron ore in that year.

The production of pig iron has been as follows:—

Country.	1871.	1881.	1891.
	Metric Tons.	Metric Tons.	Metric Tons.
United States	1,734,000	4,210,000	8,412,000
United Kingdom	6,733,000	8,511,000	7,524,000
Germany	1,564,000	2,914,000	4,641,000

With the increase in the production of pig iron its price has steadily fallen.

The production of ingot metal has been as follows:—

Country.	1871.	1881.	1891.
	Metric Tons.	Metric Tons.	Metric Tons.
United States	74,000	1,613,000	3,966,000
United Kingdom	...	1,890,000	3,309,000
Germany	...	897,000	2,563,000

These tables all tend to show what strides the iron trade has made in both the United States and in Germany in the period under review, as compared with that of the United Kingdom.

Basic Steel.—The total make of steel and ingot iron from phosphoric pig iron during 1892 amounted to 3,202,640 tons, being an increase over the make for the previous twelve months of 322,105 tons. Of this the basic Bessemer output was 2,591,374 tons, and that of the basic open-hearth 611,266 tons. Of the steel containing under 0·17 per cent. of carbon, the basic Bessemer process produced 2,043,767 tons, and the basic open-hearth 428,225 tons.* With the steel, 770,000 tons of slag were produced, containing about 36 per cent. of phosphate of lime, nearly the whole of which was used as a fertiliser. The make of the various countries for the years ending December 31, 1892, and December 31, 1891 respectively, are as follows:—

* *Iron*, vol. xli. p. 186.

Country.	1892.		1891.	
	Total.	With under 0·17 per Cent. C.	Total.	With under 0·17 per Cent. C.
United Kingdom	406,839	317,583	436,261	350,818
Germany and Luxemburg	2,013,484	1,616,783	1,779,779	1,314,781
Austria and Hungary	288,122	212,408	221,212	95,907
France	287,523	196,190	255,401	173,880
Belgium, Russia, and United States	206,667	129,028	187,882	111,172
Totals	3,202,640	2,471,992	2,880,535	2,046,558

The Duration of the Coal Supply.—R. Nasse* estimates the supplies of coal still available to be as follows in the countries named, the average annual output for the three years 1889, 1890, and 1891 being also shown :—

Country.	Available Coal.	Annual Output.
	Milliards of Metric Tons.	Millions of Metric Tons.
United Kingdom	198	184·2
Germany	112	81·8
France	18	25·3
Austria-Hungary	17	20·5
Belgium	15	20·0
United States	184	...

The author estimates that if the population of the United States increases as it has of late, then within a hundred years the density of population may be as great as that of Germany, in which case the annual output of coal would be about 1134 millions of tons. That being so, the coal supply even of the United States would not last more than about 650 years. As to Europe, the author estimates that the first failure in the supply of coal will take place in France, Austria, and Belgium, in, at the latest, 500 years time, then in the United Kingdom, and finally in Germany. In this latter country the supply of coal may last for 800 or 1000 years. The coal supply of Central Europe may possibly be at an end in about 670 years from 1890.

Mr. M. Stirrup† discusses the question of the world's supply of coal, and points out the influence of the coalfields of India, China, and Japan on the duration of the supply. Substitutes for coal are also discussed, and their distribution.

* *Stahl und Eisen*, vol. xiii. p. 306.

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